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HACKENSACK MEADOWLANDS AIR POLLUTION STUDY. SUMMARY REPORT

Byron H. Willis

Environmental Research and Technology, Incorporated

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Environmental Protection Agency
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16. ABSTRACT

The Hackensack Meadowlands Air Pollution Study consists of a summary report and five task reports. The summary report discusses the procedures developed for considering air pollution in the planning process and the use of these procedures to evaluate four alternative land use plans for the New Jersey Hackensack Meadowlands for 1990. The task reports describe (1) the emission projection methodology and its application to the Hackensack Meadowlands; (2) the model for predicting air quality levels and its validation and calibration: (3) the evaluation and ranking of the land use plans; (4) the planning guidelines derived from the analysis of the plans; and, (5) the software system.

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HACKENSACK MEADOWLANDS AIR POLLUTION STUDY - SUMMARY REPORT

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PREFACE

The Hackensack Meadowlands Air Pollution Study final report consists of a summary report, five task reports and three appendices, each bound separately. This report is the summary report. Its purpose is to present an overview of the procedures developed for considering air pollution in the urban and transportation planning process, and to describe the results of applying these procedures to the evaluation and ranking of the four alternative land use plans for the New Jersey Hackensack Meadowlands.

ACKNOWLEDGEMENTS

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The cooperation and assistance of the many personnel from EPA and NJDEP contributed greatly to the success of this study. The special assistance of Mr. Roland S. Yunghans and Dr. Edward B. Feinberg, Environmental Scientists, Office of the Commissioner, NJDEP, and Mr. John Robson, Land Use Planning Branch, Office of Air Programs, EPA, is appreciated.

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1. INTRODUCTION

1.1 Background to the Study

In response to the recognized hazards to human health, damage to vegetation and property, and degradation of the general quality of life, there is nearly universal concern for the problems of air pollution and its abatement. Currently, extensive efforts are being devoted to programs of air pollution control by federal, state, and local agencies to achieve ambient air quality standards through the direct regulation of source emissions. While such control measures are necessary to cope with the magnitude of current air pollution problems, there is a growing concern that these measures may not be appropriate to achieve long-term solutions.

Rather, it is now widely suggested that air pollution, as well as other environmental concerns, be addressed in terms of more fundamental sources of the problem, such as population growth, energy consumption, utilization of land and natural resources, and management of waste products. In particular there is wide recognition of the need to incorporate the consideration of air pollution within the planning process. One reason is that the planning process is especially well suited to the consideration of the relationships between air pollution and the many technical, social, economic, and political factors that influence potential long-term solutions. Another reason is that air pollution is only one of a multitude of problems and issues that compete for the limited resources of society and the economy; the planning process represents a rational, systematic means for examining regional needs and determining priorities to satisfy such needs.

Yet despite this concern for achieving long-term solutions through orderly comprehensive planning, there is little evidence that air pollution has ever been a serious consideration in the development and implementation of a land use or transportation plan. One of the most fundamental reasons for this lack of attention is that planners currently have neither the expertise nor the analytical tools and methodologies required to assess the air pollution consequences of planning alternatives. In recognition of these factors the U. S. Environmental Protection Agency (EPA) has undertaken a number of research studies to stimulate greater consideration of air pollution in the land use and transportation planning process, especially through the development of methodologies and guidelines for the assessment of air quality associated with proposed land use plans.

In like manner the New Jersey Department of Environmental Protection (NJDEP) has become acutely sensitive to the finite and interrelated nature of the air, water, and land resources of the state. By virtue of its location in the heart of the Washington-New York-Boston megalopolis, New Jersey is experiencing tremendous growth pressures even though it already is one of the most highly urbanized and industrialized states in the Union. While the overwhelming majority of its efforts have been devoted to correcting existing environmental abuses, the Department is looking toward new ways to plan for orderly growth which will protect the quality of the environment.

A particularly important example of New Jersey's concern for the environment and its approach to improving environmental quality through land use planning is illustrated by the State's attempt to reclaim and develop the Hackensack Meadowlands of northern New Jersey. In 1968, the New Jersey Legislature passed the "Hackensack Meadowlands Reclamation and Developme-

Act"[1] creating a commission with the authority to prepare, adopt, and implement a master plan for the orderly development of the district. As a consequence, a number of alternative comprehensive land use plans have been prepared to complement previous development in the district and to correct existing imbalances in regional land uses.

The New Jersey Hackensack Meadowlands District is a tract of land measuring approximately four miles by eight miles extending in a north-south direction along the Hackensack River. As shown in Figure 1, the Meadowlands is located at the hub of the New York-New Jersey metropolitan area. Within a five-mile wide zone around the Meadowlands is Manhattan immediately across the Hudson River to the east, Jersey City and Newark to the south, Paterson and Passaic to the northwest, and Hackensack to the north. Today, the Hackensack Meadowlands consists largely of meadows, marshes, and salt-water swamps. Of its nearly 20,000 acres only 7000 are committed to permanent uses. These consist largely of transportation networks (highways, railroads, and an airport), distribution centers (freight terminals, warehouses, storage tanks, and utility transmission lines), and solid waste disposal (over 30,000 tons per week from more than 100 municipalities).

Planners of the Hackensack Meadowlands Development Commission (HMDC) envision developing the Meadowlands in order to provide more than 300,000 jobs and homes for some 185,000 persons by 1990 while preserving nearly 5000 acres for conservation land and open space.[2] However, water pollution, air pollution, and dumping of solid wastes have damaged the natural ecology of the tidal marsh and have created an unsightly blighted area. Planners of the HMDC recognize that the ultimate success of their plans to provide housing, employment, and economic development for the region depends on the restoration of the natural environment, not upon its exploitation.

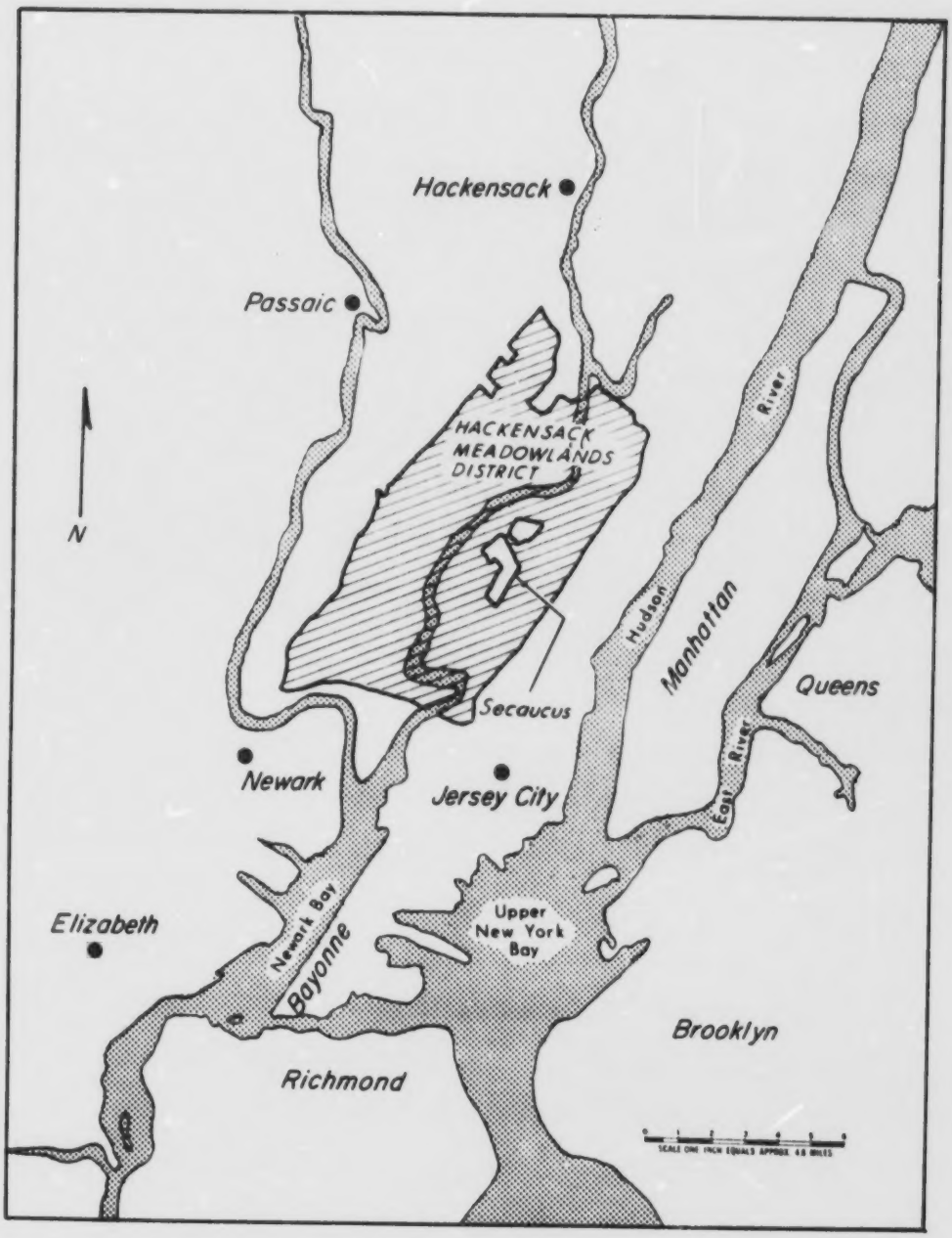

Figure 1 Location of the Hackensack Meadowlands District

Consequently, EPA and the New Jersey Department of Environmental Protection have sponsored a study addressed to the mutual concerns of both agencies for improving future air quality through the planning of land use and transportation activities. In particular, the two fundamental objectives of this jointly sponsored study are: (1) to develop a broad-based methodology for considering air pollution in the formulation and evaluation of alternative urban plans; and (2) to demonstrate in detail this methodology through its direct application to the planning alternatives developed for the New Jersey Hackensack Meadowlands District.

1.2 Objectives and Scope of the Study

Environmental Research & Technology, Inc. (ERT) was selected to undertake this study to Initiate air pollution considerations in the development, evaluation, and selection of alternative land use plans for the New Jersey Hackensack Meadowlands. The general objectives of the effort were to:

1. Develop procedures for incorporating air pollution considerations into the land use and transportation planning process.
2. Develop analytical tools and methodologies necessary to permit planners to carry out these procedures.
3. Perform an analysis of the air pollution potential associated with alternative comprehensive land use plans for the Hackensack Meadowlands in the 1990 time period.
4. Prepare a planning guidelines document which will enable urban and transportation planners to introduce air pollution considerations into the planning process.

5. Provide the New Jersey Department of Environmental Protection with an operational capability to use these procedures and methodologies to assess newly developed land use plans or modifications to existing planning alternatives for the Hackensack Meadowlands.

In carrying out these objectives the scope of the study was limited to the analysis and comparative evaluation of four alternative comprehensive land use plans for the Meadowlands for the 1990 time period. The assessment of air quality was restricted to the consideration of regional scale concentrations for annual averages and for summer and winter seasonal averages. Assessment of microscale air quality impacts, i.e., variations in concentrations over small distances and short time averaging periods, was not within the scope of this study. Five pollutants were considered: total suspended particulates (TSP); sulfur dioxide (SO_2); carbon monoxide (CO); total hydrocarbons (HC); and nitrogen oxides (NO_x). The analysis also included the influence of emission sources outside the Meadowlands on air quality within the planning region. The study was further restricted to the use of available emissions data and air quality measurements data for model validation.

Finally, the scope of the study called specifically for the development of analytical methodologies: (1) for estimating total future (1990) air pollution emissions for an urbanized area; (2) for translating projected emissions into predictions of future (1990) air quality levels; and (3) for the evaluation and ranking of alternative urban plans.

1.3 Structure of the Final Report

The final report describes the two major achievements of this study: (1) the development of the AQUIP System, a methodology for considering Air Quality in Urban and Industrial Planning; and (2) the application of this methodology to the evaluation and ranking of four land use plans for the New Jersey Hackensack Meadowlands District.

The Hackensack Meadowlands Air Pollution Study final report consists of a summary report, 5 task reports, and 3 appendices, each bound separately. Specifically, these reports include:

- The Hackensack Meadowlands Air Pollution Study-Summary Report (ERT Document No. P-244-SR)
- The Hackensack Meadowlands Air Pollution Study Task 1 Report: Emissions Projection Methodology (ERT Document No. P-244-1)
- The Hackensack Meadowlands Air Pollution Study Task 2 Report: Development and Validation of a Modeling Technique for Predicting Air Quality Levels (ERT Document No. P-244-2)
- The Hackensack Meadowlands Air Pollution Study Task 3 Report: The Evaluation and Ranking of Land Use Plans (ERT Doc. No. P-244-3)
- The Hackensack Meadowlands Air Pollution Study Task 4 Report: Guidelines for the Consideration of Air Pollution in Urban Planning (ERT Doc. No. P-244-4).
- The Hackensack Meadowlands Air Pollution Study Task 5 Report: The AQUIP Software System User's Manual (ERT Doc. No. P-244-5).
- The Hackensack Meadowlands Air Pollution Study Appendix A: Plan Data Sets and Conversion Factors Catalog (Appendix to the Task 1 Report), (ERT Doc. No. P-244-1A).

- The Hackensack Meadowlands Air Pollution Study Appendix B: Current and Background Emission Inventories (Appendix to the Task 1 Report), (ERT Doc. No. P-244-1B).
- The Hackensack Meadowlands Air Pollution Study Appendix C: Program Listings (Appendix to the Task 5 Report), (ERT Doc. No. P-244-5C).

The five task reports correspond directly to the five major tasks around which the study was organized. These reports provide a complete and detailed discussion of the approach, data, assumptions, results and conclusions for each task. In addition, two separately bound appendices to the Task 1 Report document the data sets and specific calculation routines used for estimating emissions in the study. Similarly a separately bound appendix to the Task 5 Report documents the AQUIP System software.

A summary description of the work performed and results obtained in the study is presented in this Summary Report. The material is taken from each of the study task reports, but is organized and presented in relation to overall study objectives. In particular, Section 2 presents an overview of the procedures for incorporating air pollution in the planning process. The detailed discussion of those procedures is found in the Task 3 Report.

Sections 3, 4, and 5 present summary descriptions of technical methodologies and analytical tools developed explicitly to permit the planner to carry out the general procedures. Specifically, Section 3 summarizes the emissions projection techniques, which are described in detail in the Task 1 Report. Section 4 summarizes the air quality projection techniques and validation procedures, which are described in detail in the Task 2 Report. Section 5 summarizes the computer programs, data sets, and information flow associated with the AQUIP System, the basic tool for carrying out the air

quality assessment procedures. The detailed description of the AQUIP System software is given in the Task 5 Report.

Section 6 presents a summary of the results of the air quality analysis of the Meadowlands land use plans using the AQUIP System. The detailed discussion of the comparative evaluation of the alternative plans is given in the Task 3 Report.

Section 7 summarizes the conclusions and planning guidelines derived from the Meadowlands air pollution study. The complete planning guidelines are presented in the Task 4 Report.

Finally, Section 8 presents a summary of major conclusions from the study and lists recommendations for further research efforts.

It is expected that this Summary Report will receive a wider distribution than the individual task reports and therefore is oriented toward providing summary information and general descriptions of techniques and results. Planners, air pollution control officials, and other readers who desire to use the procedures and analytical methodologies described herein should obtain copies of the detailed task reports that are applicable to their particular interests.

2. GENERAL METHODOLOGY FOR CONSIDERING AIR POLLUTION IN THE PLANNING PROCESS

2.1 The AQUIP System

In response to the general requirements identified in a survey of planning agencies, a methodology has been developed which permits planners to incorporate air pollution considerations within the planning process. The elements of this methodology consist generally of: (1) a set of procedures for collecting, processing and interpreting land use and other input data; (2) a set of procedures for generating air quality information from such input data; and (3) a set of procedures for the evaluation and ranking of alternative land use plans. This combination of methodologies, procedures and analytical tools represents a system for the analysis of air pollution associated with land use and transportation plans. This system has been designated as the AQUIP System (Air Quality for Urban and Industrial Planning), and is represented schematically in Figure 2.

The AQUIP System is a computer-oriented set of procedures involving the planner in an iterative cycle of plan evaluation and modification consisting of the following basic steps:

1. The preparation of input data descriptive of the land use or transportation plan.
2. The conversion of these data into pollutant emissions data.
3. The prediction and display of mean ambient pollutant concentrations within the area of interest.

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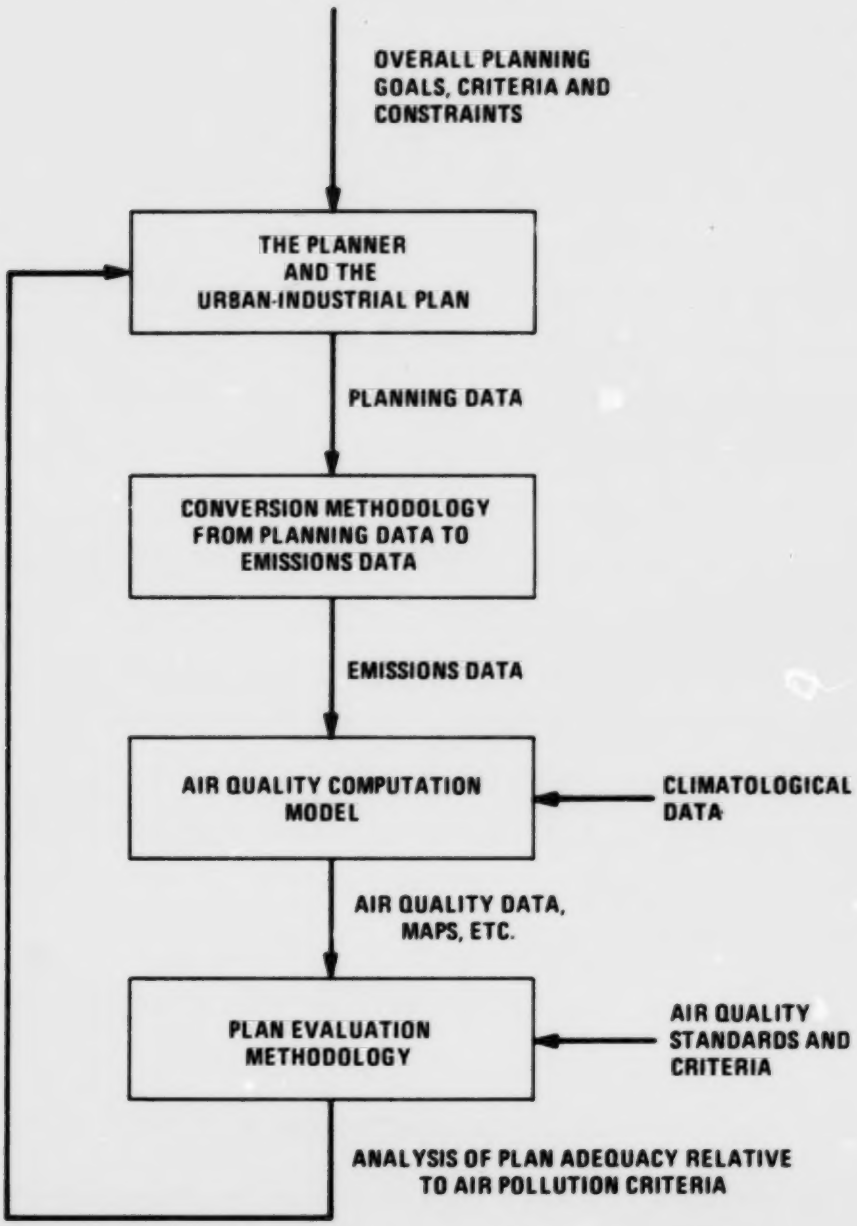
OVERALL PLANNING GOALS, CRITERIA AND CONSTRAINTS
THE PLANNER AND THE URBAN-INDUSTRIAL PLAN
PLANNING DATA
CONVERSION METHODOLOGY FROM PLANNING DATA TO EMISSIONS DATA
EMISSIONS DATA
AIR QUALITY COMPUTATION MODEL
CLIMATOLOGICAL DATA
AIR QUALITY DATA, MAPS, ETC.
PLAN EVALUATION METHODOLOGY
AIR QUALITY STANDARDS AND CRITERIA
ANALYSIS OF PLAN ADEQUACY RELATIVE TO AIR POLLUTION CRITERIA
6414

Figure 2 The AQUIP System Conceptual Design

4. The evaluation and ranking of the plan with respect to other plans through analysis of air quality contours and the computation of quantitative measures of impact.

5. The subsequent modification of the plan or the input data and the repetition of the process.

Of these five steps the first and last require the direct involvement of the planner to specify and manipulate planning data, to assess the degree to which a plan satisfies the planning objectives and constraints, and to specify changes to the plan as deemed necessary. The other steps involve directly the use of computer-based models and data management programs to perform the required air quality projections and data calculations.

A basic feature of the AQUIP System is that it permits the direct input of land use planning data. As a result it can be used to compute ambient air quality concentrations related to specific land use activities. The primary outputs of the AQUIP System are in the form of computer-generated maps and tabular listings of data. Computed concentrations for each of the pollutants may be displayed as isopleth contours and overlayed on base maps of the planning region, permitting a rapid visual correlation between air quality concentrations and land use activities.

The heart of the AQUIP is the mathematical diffusion model used to compute pollutant concentrations based on source emissions input data and meteorological parameters. The model is a version of the Martin-Tikvart advection-diffusion model which has been extensively modified by ERT to improve the accuracy of calculating concentrations over short transport distances and to improve flexibility in the use of the model.

Another essential element of the AQUIP System is the air quality data management and impact analysis software. In this portion of the system the user can specify arbitrary measures of impact and can manipulate air quality data, emissions data, land use data, air quality standards, or any other data set to calculate such impact measures. Calculated data can be tabulated or presented graphically, showing for example, the distribution of air quality concentrations, emissions densities, impact parameters, land use densities, or other data of interest to the planner. Furthermore, such data can be used to compare and rank plans in terms of air quality standards and other criteria as specified by the planner.

2.2 Basic Air Quality Analysis Considerations

The procedures developed for the evaluation and ranking of alternative land use plans are based on determining air quality on a region-wide geographic scale for annual and seasonal average pollutant concentrations. Furthermore, the evaluation of air quality associated with a plan focuses on the analysis of four items:

1. The degree of compliance with ambient air quality standards.
2. The degree of impact on regional levels of air quality.
3. The degree of impact on specific receptors or land use categories that are especially sensitive to the effects of pollutants.
4. The indication of ways to modify plans to improve air quality.

Procedures for examining compliance with air quality standards involve the calculation of projected air quality contours over the planning region.

The maximum values of predicted air quality levels are then compared with the appropriate ambient air quality standards.

Procedures for examining the impact of land use plans on regional air quality are based first on the examination of spatial patterns of air quality and secondly on the calculation of quantitative measures of impact for each pollutant. The examination of the isopleth contours of pollutant concentrations over the planning region indicates the location of regions of low and high pollutant concentrations and also permits the visual examination of the influence of the type, location and intensity of land use activities on the air quality contours. The calculation of impact measures permits the comparative evaluation and ranking of alternative plans through the quantitative assessment of their impact on regional air quality.

An especially important aspect of the analysis and evaluation of land use plans is the analysis of impact of air pollution levels on specific high-risk receptors and land use categories. The analysis procedures are based both on the examination of the location of critical receptors relative to air quality contours and on the calculation of quantitative measures of impact.

Procedures for plan modification using the AQUIP System consist of general guidelines based on the tabulation of the annual emissions per acre for the different land use categories analyzed for the Hackensack Meadowlands. These data show the relative sensitivity of air quality levels to such plan design factors as the mix, location, and intensity of land use categories. Such data can be used, for example, to identify land use categories which can be located within the plan without any significant impact on regional air pollution concentration levels, but which substantially reduce exposures of critical receptors to pollutants.

2.3 Methodologies for Plan Evaluation and Ranking

Procedures were developed for the evaluation and comparative ranking of alternative land use plans based on the interpretation of three basic types of information: land use data, air quality data, and air quality criteria. The basic methodologies developed for plan evaluation and ranking consist of the analysis of regional air quality based on the calculation of quantitative measures of impact and on the graphical display of air quality contours. The interpretation of air quality contours relies largely on visual examination and subjective judgment rather than on quantitative analysis. On the other hand, quantitative impact measures permit analytic evaluation, but subdue the physical and intuitive interpretation of the results. Consequently, the key issue involved in the development of procedures for plan evaluation and ranking concerns the role of subjective judgment on the part of the planner: the interpretation of quantitative evaluation and ranking data and its importance relative to other planning issues ultimately is a value judgment.

In this study the quantitative measures of impact that were found to be most useful and meaningful in both plan evaluation and ranking were: (1) measures of integrated receptor exposure, and (2) measures of average receptor exposure. The integrated receptor exposure for a given plan is calculated by superimposing an arbitrary grid system on the planning region, forming the product of the number of receptors per grid cell times the pollutant concentration within the grid cell, then summing this product over all grid cells within the planning region. This impact measure physically represents an indicator of the cumulative values of receptor exposures within the plan. By contrast, the average receptor exposure impact measure is

calculated from the integrated exposure measure by dividing the resultant integrated exposure measure by the total number of receptors within the plan. Consequently, the average exposure measure has units of pollutant concentration and physically represents an indicator of the average concentration to which any given receptor within the plan will be exposed.

The receptors investigated in terms of these quantitative measures of impact were people and land. Two categories of people receptors were used: total population and student population. Four categories of land receptors were used: total land area, residential land area, open space land area, and the combination of commercial and industrial land area. In the analysis of the Hackensack Meadowlands plans, the average total area exposure was examined as the primary measure of regional air quality levels and the average population exposure impact parameter was examined as the principal measure of impact on critical receptors. However, quantitative impact measures were calculated for all combinations of pollutants and receptor categories. In addition, the AQUIP System permits a significant amount of flexibility in defining and calculating other quantitative measures of impact and in specifying air quality criteria other than ambient air quality standards for use in the evaluation.

The specific requirements for the quantitative ranking of alternative land use plans differ slightly from the requirements for the analysis and evaluation of plans. The basic need for plan ranking is to generate a single number or ranking index that can be calculated for each plan to permit the relative ranking of the plans. This ranking index may be associated with the impact of a single pollutant, thereby allowing a pollutant by pollutant comparison and ranking, or may be associated with the combined impact of all pollutants (i.e., a multipollutant air quality index).

Although it is required that the ranking methodology be based on a formula in order to permit the ranking to be based on quantitative criteria precisely stated in objective terms, it is evident that no ranking index is unique or absolute. In fact, it is desired that the ranking scheme be sufficiently flexible to accommodate the subjective values of the planner and his particular circumstances in formulating the ranking index.

A brief survey of the literature dealing with the general multipollutant air quality indices indicates that despite the fact that many such indices have been proposed, all exhibit some degree of difficulty in accurately characterizing the status of regional air quality in terms of multipollutant impact, and few were found to be directly applicable to the ranking of land use plans.

Three specific ranking schemes were examined in detail to determine their suitability as a meaningful and useful index for ranking alternative land use plans. The methodology finally selected for use in the analysis of the alternative land use plans for the Hackensack Meadowlands is designated as the Normalized Impact Parameter Ranking Index. The selected ranking index is described in detail in Section 5.3.3 of the Task 3 Report.

3. METHODOLOGY FOR PROJECTING EMISSIONS

3.1 Basic Features of the Procedures

One of the major objectives of the study was to develop a methodology to aid planners in determining air pollutant emissions directly from land use and transportation activity data.

The basic requirements established for the emission projection methodology were: compatibility of emissions data with both planning information and dispersion model formats, applicability to general situations and not just to the Meadowlands, reliance upon existing state and federal emissions inventory data, and provision for updating. These shaped the procedures developed. A five-step procedure was formulated to transform data on levels of activity into fuel demand, and fuel use into emissions. These transformations rely upon empirically derived "default parameters" as well as upon published government data, such as air pollutant emission factors.

The procedures are applied and tested in two phases: in the first phase current planning data and current emissions are correlated to produce projecting indices. In the second phase these projecting indices are modified to reflect future time periods and are applied to planning data so as to generate future emission levels. The study was concerned as much with the applications of this second phase to the Hackensack Meadowlands land use plans, as with the development of the procedures themselves.

3.2 General Description of the Procedures

Procedures presently used to estimate emissions from land use and transportation planning data often emphasize empirical derivation of emission indices as a one-step function of "activity categories." In this study,

however, a multi-step approach was developed so that: (1) all assumptions and constraints involved in transforming the levels of activities into emissions could be examined; and (2) procedures for updating the information which the planner does not directly input could be specified.

In response to the study objectives a five-step procedure was formulated:

Step 1 - Activities: For each land use or transportation planning category identified for analysis, the "level of activity" is specified, such as 20 dwelling units per acre for residential density.

Step 2 - Activity Indices: For each category of activity, "default parameters" for determining fuel requirements are developed, such as 10 BTUs (British Thermal Units of heat demand) per hour per square foot of residential floor area.

Step 3 - Fuel Use: For each category of activity (and geographical sub-region of the study area) default parameters for the propensity to use different fuels are applied to the fuel requirements, such as the degree to which oil is used (75%) rather than natural gas (25%) for home heating.

Step 4 - Emission Factors: For each category of activity, engineering estimates of fuel and non-fuel (process) related "emission factors" are developed and applied directly to fuel use and process rates to determine emissions, such as 10 pounds of particulates per 1000 gal. of fuel oil burned.

Step 5 - Emissions: Emissions calculated from fuel and process sources are adjusted for season of the year, based on temperature variation (degree days) and default parameters representing the percent of fuel used for "space heating" purposes.

Of particular importance in this study was the application of these five-step procedures in two distinct and consecutive phases. In the first phase

current planning data and current fuel use are correlated to produce projecting indices - the default parameters. In the second phase these projecting indices are modified to reflect future time periods and are applied to planning data so as to generate future fuel demand and emission levels. Current data on fuel use and emission factors are likewise used to predict future information when better estimates are not known. The first phase analysis provides the majority of the default parameters to be used in the second phase in conjunction with the planner's own inputs.

By focusing attention on such procedures for determining current emission inventories, it is easier to develop techniques for estimating future emission inventories. This is important since future inventories must depend directly upon planning related data. Furthermore, it is only through an excellent understanding of the relationship between planning and emissions for current inventories that the necessary conversion factors to project future emissions can be developed.

Another especially important consideration in this study was the development of procedures for allocating emissions to a grid system as required for input to the diffusion model. Emission inventories are too often tied to the grid cell system that is used for modeling purposes. Much of the original information obtained by land use zones or political jurisdiction is lost in the process of transferring the data to the area source grid cells. The grid cell size cannot be changed at a later date and a great deal of manual input of data must be undertaken. To avoid these problems, a powerful and innovative technique was developed as part of the LANTRAN program to make the processing of information independent of grid size. The key to the technique is the initial listing of land use activities and related characteristics in a computer

data bank by geographical coordinates (such as UTM - Universal Traverse Mercator - Coordinates) and land use zones. Emissions data for each land use zone are computed by referencing the conversion factors catalog. Then, any specified grid size can be superimposed and the emissions contained within each grid cell calculated. Thus, if changes are to be made in the initial land use data or if a different grid cell system is desired, the incremental changes can be made without destroying the entire data system. This feature provides for the maximum convenience in updating basic data and for maximum flexibility in the use of the data.

A final consideration of basic importance concerns procedures for estimating emissions when confronted with inadequate data. To put such general procedures into practice requires assumptions and approximations: the data may not be available according to the land use zones and political jurisdiction desired; many of the parameters necessary for the activity indices contained in the conversion factors catalog may be missing from the data base. For missing data the concept of "default parameters" was developed. If information is desired, for example, according to a detailed industrial classification for the propensity to use different fuels but data are available only on an aggregated basis for all industries in the region, a default parameter is used to assign the industry-wide factor to each individual industry. If, at a later date, specific information for an industry becomes known, then it can be incorporated into the conversion factors catalog in place of the default parameter.

3.3 Illustration of the Estimation Procedures

Three examples can be discussed briefly to show the application of these procedures to planning activity data, in general, and to the Meadowlands plans, in particular. The three examples show: (1) a residential land

use zone represented as an "area-wide" source; (2) an industrial activity represented as a single "point" source; and (3) a highway segment represented as a "line" source.

3.3.1 Example of Area Source Emissions Estimation Procedures

For a residential land use category there are several planning inputs that are required, referred to by the steps in the five-step procedure previously outlined:

Step 1 - The density and acreage can be used to determine the number of dwelling units.

Step 2 - The average number of rooms and type of dwelling unit can be used to determine the heating requirement (fuel demand) per dwelling unit.

Step 3 - The mix of single family homes, town houses and apartments can be used to determine what fuels will be burned and with what size equipment. This procedure was very elaborate in the case of the Hackensack Meadowlands plans: clusters of apartment complexes separated by open water were often heated from a single central system.

Several default parameters may also be required, particularly in Step 2. Current data on activity levels and fuel use can be used to calculate a default parameter for heating demand - British Thermal Units per dwelling unit (BTU/d.u); this value can be adjusted for a future time period and for differences between residential categories, particularly for the number of rooms per dwelling unit.

It is necessary to answer several important questions concerning how the fuel demand will be satisfied:

1. What fuel will be used (oil, coal, gas, steam, or electricity)?

2. What other home activities in addition to heating will use the fuel (cooking, hot water)?

3. What type of fuel-burning apparatus will be used (individual home heating, or a central heating system for several thousand dwelling units)?

National or regional default parameters can usually be relied upon to answer the first two questions, but the third question is basically a planning decision. There is a significant trend toward centralized heating and cooling systems for reasons of economy in developments such as those contemplated for the Meadowlands. The density of development and the large scale of each single complex is such that many of the procedures formulated for the Meadowlands plans cannot be translated into average suburban single-family residential areas.

Step 4 - For each fuel and type of fuel burning equipment (individual house or central system), the Environmental Protection Agency (EPA) has published emission factors[3].

Step 5 - These factors are used to translate the amount of fuel burned into the quantity of emissions for various pollutants. The size of the fuel burning installation determines which factors should be used and whether or not emission control devices are likely to be used.

3.3.2 Example of Point Source Emissions Estimation Procedures

For an industrial activity the problem may be more complex. In dealing with an existing major emitter represented as a point source, adequate emissions information may be available from a current inventory; however, it is unlikely that the present level of activity or projected changes in that level

will be known. Conversely, planning information tends to deal with industries by broad categories and rarely with a specific firm and its characteristics which will influence the level of emissions at a particular location. The land use planner does work with parameters such as acres and lot coverage which can yield an estimate of the number of square feet of floor space for a new facility (Step 1). In the case of the Meadowlands plans, for example, only the area of each industrial lot (in multiples of 10 acres) was specified by the planners.

Empirically derived estimates of BTUs per square foot for heating purposes (Step 2) show great variation; even greater variation is exhibited in the percent of fuel used by industries for heating. It may be 100% for a warehouse and close to zero for a foundry. Propensities to use different fuels (Step 3) may be derived empirically by industrial category, such as the two-digit or four-digit Standard Industrial Classification (SIC) adopted by the U.S. Department of Commerce for their Census of Manufacturing.

The least reliable information involves separate process emissions from industrial sources, such as the evaporation from a tank farm. Source emission inventories have generally been incomplete in this area; therefore, little empirical data are available from which to derive default parameters. Furthermore, where emission factors have been determined, they are related to process rate: the total quantity of material processed per unit time for the operation producing the emissions. Process rate has not as yet been correlated with parameters that are readily available to the planner; virtually no planning effort would include projections of process rate. Therefore, very crude default parameters have been developed in this study to relate process emission by activity category directly to fuel emissions or to activity level, such as employment.

If an activity such as an industrial land use zone does not generate a large amount of emissions, it should be aggregated into an area source for modeling purposes rather than considered a separate point source. Default size criteria were determined for each activity category to allow the planner to decide, objectively, whether a particular development should be considered a point source or not.

3.3.3 Example of Line Source Emissions Estimation Procedures

The procedures for determining line source emissions from a highway network are quite simple. Activities (Step 1) are multiplied directly by emission factors (Step 4) to produce emissions (Step 5). The EPA emission factors vary by vehicle class; in addition, the factors for certain pollutants vary with speed. Transporation planners routinely determine all of the activity data needed. The procedures use default parameters for vehicle class mix, model year mix, and average speed together with the appropriate emission factors where local data are not available. Whether or not a particular traffic segment should be a line source or an area source can be determined by a size criterion, based on vehicle miles per unit time.

3.3.4 Other Estimation Procedures

The procedures to go from activity levels (Step 1) to emission strengths (Step 5) for all other activities represent combinations of and modifications to these three examples. In many cases, commercial, institutional, or transportation activity emissions can be determined as a function of the residential activities they serve. This is particularly relevant when a planned development having apartments, offices, stores, and parking areas built as one unit is involved.

Certain activity categories, such as parks, were considered to have negligible emissions when averaged over a season or the year and were, therefore, not included in the analysis. Other categories, such as the airport, did not have significant fuel-related emissions but did have significant process emissions which were related directly to the level of activity (number of flights per year). In some cases the level of activity may indicate indirect sources of emissions, such as transportation usage for a sports complex.

In the study, the area outside the Meadowlands planning district was treated as the background region for purposes of determining emissions. The same five-step procedures were followed, but both the activity categories and the actual data available were far less detailed. Most activity categories were treated as area sources and were aggregated from the county level to grid cells of various sizes. Residential and non-residential square feet of floor space (Step 1), BTU's per square foot (Step 2), propensity to use oil versus gas (Step 3), and residential, industrial, and commercial fuel combustion emission factors (Step 4) were used to determine emissions (Step 5). Most other categories such as transportation, evaporation and incineration, were treated as activities (Step 1) times emission factors (Step 4) yields emissions (Step 5). Large separate sources, such as power plants, were separately projected to 1990 based on current data and appropriate changes in their emission characteristics; these were treated as point sources. Major roadways near the Meadowland were treated as line sources using the aforementioned procedure.

3.4 Computational Techniques

The actual calculations to determine 1990 source emissions for the Hackensack Meadowlands plans were carried out using computer routines within

the AQUIP software system. All data inputs were completely standardized in computer form, and all decisions involving the treatment of a specific land use zone were likewise standardized in computer form.

Such computational procedures are quite complex. They include flags which indicate, for example, that three residential zones are served by one central heating system and should therefore be recoded to the location of that central heating system. Such flags provide the planner with the flexibility to treat each land use zone uniquely, and thus provide a very powerful analytical tool. They are, however, very time-consuming to formulate and translate into the required objective computer form, and are very much application specific rules, based on specific planning assumptions.

To illustrate, the calculations required for schools are complex because the heating requirement for a school (BTUs per classroom) is a function of the residential area it serves. Flags in the computer program would show, for example, that a particular school (and its commensurate heating requirement) are linked to certain residential areas. Then, specific planning-related information is needed on the number of pupils per classroom, the number of pupils or children per dwelling unit, and the percentage of these children who would go to the type of school under consideration--primary or secondary. Such information was determined in this study in consultation with the Meadowlands planning staff.

A similar complex linkage occurs in the computation of emissions for certain commercial activities, such as neighborhood shopping areas, where the amount of space was found to be a function of the size of the residential apartment clusters as specified in the Hackensack Meadowlands Zoning Regulations; furthermore, because the development is most likely to be built

as one unit, it was assumed that the heat would be supplied by the same central system that serves the apartments.

3.5 Conclusions

The application of the emissions projection methodology to the Meadowlands plans showed that the five-step procedures were workable and, in fact, quite adaptable to the land use considerations that were encountered. In particular, the development of a conversion factors catalog and sets of default parameters demonstrated that the planner need input only planning-related data to use a tool such as the AQUIP System.

However, it was found that the planner must specify data he does not normally deal with, such as the sizes of developments in terms of their heating requirements, and the types of manufacturing operations anticipated. Furthermore, the level of detail available for empirically deriving the default parameters was unsatisfactory for discerning between related activities; this was particularly true for deciding fuel use and determining process-related emissions. Consequently, the greatest need for further work involves the empirical derivation of activity indices and default parameters. The availability of current region-wide emissions data for model validation and for the determination of the projective indices was also inadequate.

The methodology, as developed and applied allows meaningful comparisons to be made among the alternative Hackensack Meadowlands land use plans. In addition the methodology should be useful in determining the effect of incremental changes in a plan, or in the testing of additional plans.

4. METHODOLOGY FOR PROJECTING AIR QUALITY

4.1 General Description of the Air Quality Projection Model

The basic goal of the atmospheric diffusion model development and validation effort has been the calculation of seasonal and annual average concentrations for the pollutants of interest (SO_2, CO, NO_x, hydrocarbons and particulates) expected within the planning region for the emission patterns associated with various possible land use distributions that may exist in 1990.

The model used for projecting air quality is called the ERT/MARTIK atmospheric diffusion model. It is a gaussian plume model that follows the physical and mathematical basis described by Martin and Tikvart[4] and documented in the report on the Air Quality Display Model.[5] Numerous modifications have been incorporated into the ERT/MARTIK model to improve computational accuracy for receptors near source areas, to permit tradeoffs between accuracy requirements and computation time, to permit improved flexibility in the treatment of rectangular area sources of any size and location, and to permit direct treatment of line sources.

The principal modifications incorporated into the ERT/MARTIK model include:

1. Treatment of Area-Source Emissions

A major improvement of accuracy of representation was made by replacing the virtual point source approximation to area source emissions with a numerical integration procedure over the area source. The use of a virtual point source representation for area sources results in a "sawtooth" concentration profile in the crosswind direction at short distances downwind

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from a group of area source cells. The numerical integration scheme avoids this difficulty. The integration is accomplished by summation of elemental strips of the area source and may be used for any specified source height and any wind direction. For efficiency of calculation, the computation routine uses fewer elemental strips when the source receptor distance is large and where finer elements would not significantly change the computed concentrations. The maximum number of elemental strips to be used is externally specified as a part of a set of input parameters that control computational accuracy.

2. Treatment of Line-Source Emissions

Emissions from roadways may be represented as line sources. In order to estimate the downwind concentration from these sources for any possible wind direction and elevation, another numerical integration routine was developed. This procedure involves approximating short segments of the line representation with upwind virtual point sources. In a manner similar to that of the area source integration, the number of virtual points per unit length used depends upon the distance to the receptor and the desired accuracy.

3. Flexibility of Operating Mode and Output Format

A major feature of the ERT/MARTIK model is the ability to isolate the contributions to the concentration at receptors by simple choices of input parameters. Thus, for example, the contributions from individual sources, wind directions, or stability classes may be easily isolated.

4. Computational Efficiency Features

In addition to the controlled accuracy capabilities discussed in terms of the integration routines for line and area type sources, a number

of other specific improvements have been made to keep computation time low. These include: (1) input specification of argument value ranges for which exponentials may be approximated by simple functions; (2) simple inverse scaling of concentration contributions as a function of wind speed, for sources with zero effective plume rise; and (3) optimization of the number of source-receptor geometry calculations for a given run.

5. Compatibility with Computer Core Limitations and AQUIP System Software Interface Requirements

The model, which is compatible with IBM 360 computers, has also been specially modified to permit its use on the RCA SPECTRA 70 computer operated by the New Jersey Department of Health. Specially designed data storage and data flow routines have been developed to comply with the core limitations (i.e., 55,000 bytes) of the SPECTRA 70. Also, the model input and output routines have been integrated into the AQUIP software system (for example, the LANTRAN program which computes emissions source distributions from given planning parameters, and the SYMAP computer graphics program, which provides general display capabilities for land use, emissions and air quality data).

4.2 Basis of the Model: The Gaussian Plume Equation

The model calculations are based upon multiple applications, and integrated forms, of the gaussian plume equation, which represents the concentration pattern downwind from a point source. The general form of the equation is

$$\chi(0,0,z) = \frac{q(x,y,H)}{2\pi\sigma_y\sigma_z u} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2\right] \cdot \cdot \left\{ \exp\left[-1/2\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-1/2\left(\frac{z+H}{\sigma_z}\right)^2\right] \right\} \quad (1)$$

where

(x,y,z)	are the (upwind, cross-wind and vertical) components of a cartesian coordinate system, such that the receptor point is located at or vertically above the origin (expressed in units of length) and the source at the point (x,y,H)
H	is the effective height of emission and therefore the centerline height of the plume (length)
q	is source strength (mass/time)
σ_y, σ_z	are dispersion coefficients that are measures of cross-wind and vertical plume spread. These two parameters are functions of downwind distance and atmospheric stability (length)
u	is average wind speed (length/time)

Figure 3 illustrates the geometry for the plume equation. The source base is at z = 0 in the coordinate system, and the plume center-line reaches an equilibrium height H at some distance downwind from the source.

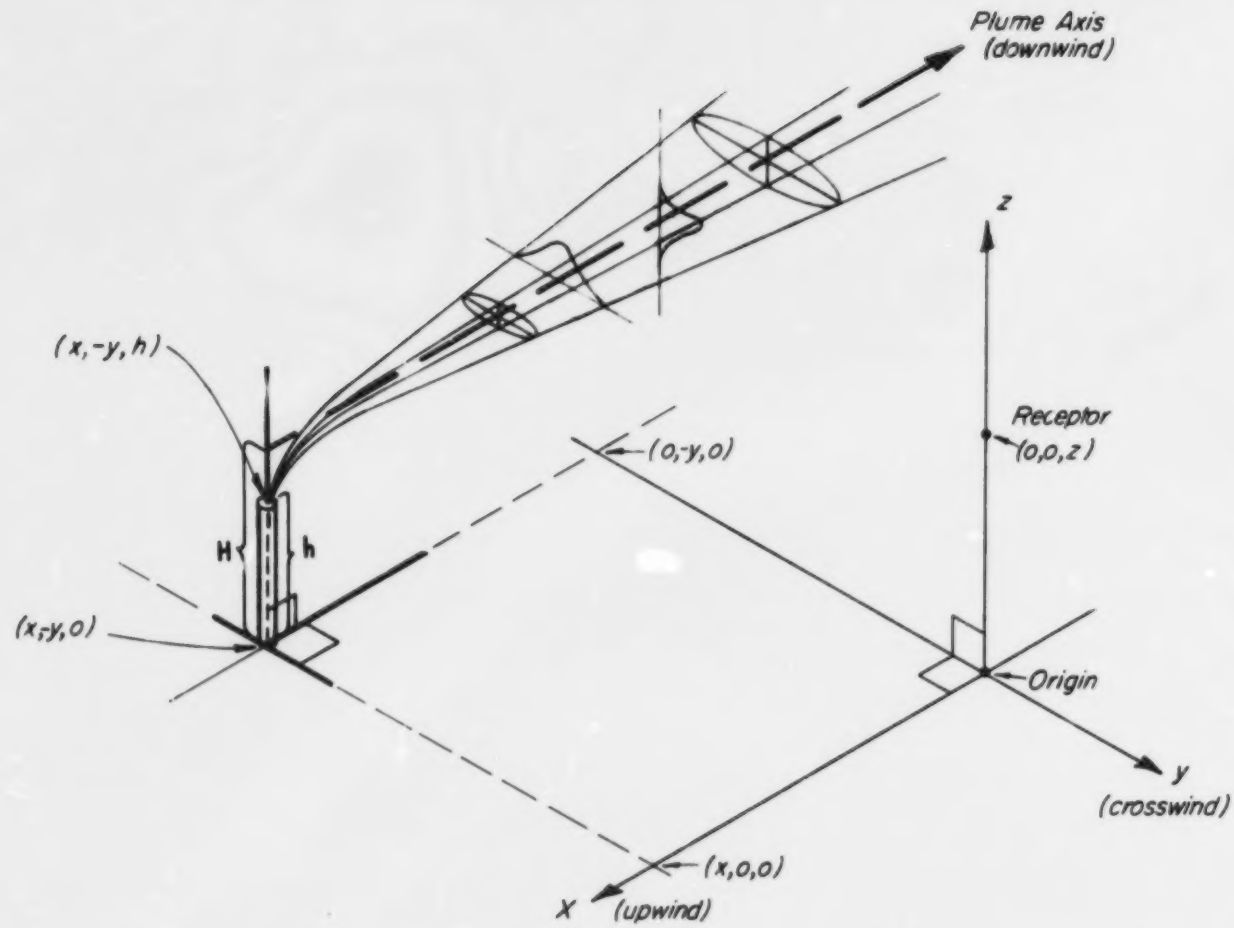

Figure 3 Coordinate System Showing Gaussian Distributions in the Horizontal and Vertical (Ref.: Turner (1969), Workbook of Atmospheric Dispersion Estimates, PHS Publication No. AP-26).

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The Task 2 Report contains a description of the gaussian plume equation, including: (1) a list of the limiting assumptions associated with its use, (2) the method of using integrated forms of the equation for the calculation of seasonal and annual average concentration levels, and (3) methods for calculating concentrations resulting from point, line and area sources, based on the plume equation.

4.3 Data Used in the Modeling Studies

4.3.1 Data Requirements

Three principal types of data are required for an atmospheric dispersion model analysis. These are:

1. Source Data

Emission data for all pollutants of interest must be available. The emission data log may contain a combination of point, line and area sources. Information required for each source includes emission rate, location of the source, and engineering data necessary to determine plume rise.

2. Transport Data

This category of data generally includes meteorological data and information on ground topography in the region of interest. The model requires climatological records indicating the joint frequency of occurrence of wind speed, wind direction and atmospheric stability classes appropriate for the model region. The influence of topographic features is generally treated by appropriate modifications to available wind speed and direction data. In the present analysis, data from Newark Airport were judged to be representative of the model region and were used without modification.

3. Concentration Data

Air quality measurement data must be used for validation of the model calculations. If it were possible to model atmospheric transport and dispersion processes with great reliability, it would not be necessary to incorporate ambient atmosphere monitoring data in the model program. However, current capabilities with models require direct comparisons of model results with actual measurements data. For the present study an array of air quality monitoring data gathered by the New Jersey Department of Health at several locations near the planning region was used as the basis for model validation.

4.3.2 Meteorological Data Selected for Use

After a review of several possiblities it was determined that the National Weather Service records for Newark Airport should be used as the meteorological input data in this study. The Newark Airport location is approximately 5 km from the southwestern corner of the Meadowlands planning region. For determination of the influence region, the Newark wind direction rose data for 1956-1965 were examined. For model validation studies, the stability wind rose data (available as output from the STAR program at the National Climatic Center, Asheville, North Carolina) for the Calendar Year 1970 were employed. For model projections to 1990, the STAR program climatological data for the 10-year period 1956-1965 were used. The 1956-1965 record represents the most recent, 10-year record of hourly observations available for use in the model projections.

4.3.3 Emission Data Selected for Use

The emission data selected for use in the model study were defined according to four geographical zones. These zones are:

Zone 1: Meadowlands plan boundary

Zone 2: Approximately 1 mile beyond the boundary of Zone 1; defined by town lines except to the south (Newark and Jersey City), and includes Secaucus.

Zone 3: Approximately 5 miles beyond the boundary of Zone 2; defined by town lines; includes Manhattan in the New York part of the region.

Zone 4: Remaining New Jersey and New York counties in the Abatement Region (1955/1966).

Other: Connecticut counties in the NY-NJ-Conn. Abatement Region

These four zones are illustrated in Figure 4. Selection rules defining the differences in the method of treatment of source emissions data in each of the four zones are described in the Task 2 Report (ERT Doc. No. P-244-2).

4.3.4 Concentration Data Selected for Use

Sources of measured ambient air quality data evaluated during the study included the New Jersey continuous air monitoring network (including two major trailer sites at Newark and Bayonne near the planning region and other nearby satellite monitoring stations) and the New Jersey high-volume sampler network. Also evaluated were data from the 38-station air quality monitoring networks operated by New York City, data obtained at Secaucus by the U. S. Public Health Service between March 1969 and February 1970, measure-

Figure 4 Illustration of the Four Geographical Zones used in the Development of the Emission Inventory.

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ments during the summer of 1966 made in support of the New York-New Jersey Interstate Abatement Activity, and other data in southern New York and northern New Jersey available in the National Aerometric Data Bank.

Several types of data from these sources were employed during trial calculations, and were examined extensively during initial validation studies. For specific calibration of the model, it was decided to use data only of the same type (from the New Jersey network), and from locations nearest to the planning region. Therefore, data from five stations in the New Jersey network (Newark, Bayonne, Jersey City, Hackensack and Paterson) were chosen. Model calibration parameters were developed for summer, winter and annual cases from these five locations.

4.4 Model Validation Procedures

4.4.1 Objectives

The primary objective of the validation effort was to assure that the model adequately predicted concentration values over the time and space scales of interest and over the range of expected input data values. Validating a model implies a detailed investigation of the model results and a comparison of those results with measured values in order to identify and evaluate discrepancies. If the model results compare well with the observed data or if, for the applications to be made, simple correction factors are deemed appropriate, the model may then be simply calibrated with the observed data. On the other hand, if systematic discrepancies are found, the investigation may suggest alterations of model parameters or of the model mechanics that would improve the representativeness of the model. A final calibration generally is required as the last stage of the validation procedure to best adjust for remaining discrepancies between observed and predicted results.

4.4.2 Procedures for Validating Models

The procedures for validating models will differ somewhat from application to application depending upon the nature and purpose of the study and depending upon the quality of the available data. The validation procedure will normally require a thorough study of the implications of model assumptions and the performance of "sensitivity" studies for various input parameters. In this study the following sensitivity tests were carried out and evaluated:

1. Inclusion of Pollutant Half Lives

The gross effects of removal processes for gaseous pollutants can be simulated by the inclusion of an exponential time decay term.

2. Refinement of Area Source Grid and Inclusion of Nearby Roadways

Minor sources in the immediate vicinity of the sampling locations will have a strong influence on air quality at the sampling locations and the resultant measurements may not be representative of regional scale air quality.

3. Incorporation of the Effects of Correlation Between Diurnal Meteorological Variations and Pollutant Emissions Rates

Emission rates of transportation and industrial related pollutants are lower during nighttime hours. Because the atmosphere is on the average more stable at night, models that do not include diurnal variations in source strength tend to overpredict seasonal and annual average pollutant levels.

4. Incorporation of Effects of Correlation Between Wind Direction and Emission Rates

Winter emission rates associated with space heating are expected to be positively correlated with the cooler northerly winds. Neglect of this mechanism causes models to overpredict space heating-related pollutant levels.

5. Modification of Dispersive Statistics

Because of reduced evaporative cooling and increased capture of incoming solar radiation in urbanized areas, thermal convection from the ground is more vigorous than in rural areas. In addition, because of their built-up nature, urban areas are aerodynamically rougher than rural areas. These two factors cause enhanced mixing of pollutants and increased plume dispersion spread rates.

6. Modification of Assumed Mixing Depths

For similar reasons the mean mixing depth for urban areas is expected to be larger than that assumed for rural areas.

7. Modification of Airport Velocity Measurements

Several modifications to the airport wind speed measurements are possible:

a. The low level measurements of wind velocity at Newark airport are on the average lower than wind speeds existing at higher levels, causing different effects on ground-level concentrations depending on source elevation.

b. The wind speed frequency records classify the lowest speed cases (calm) as values between 0 and 3 knots (1.54 m/s). The average wind speed that really

occurs during "calm" conditions (velocities too low to be reliably read by the anemometer) is likely to be skewed toward the 3-knot limit.

c. The effect of the increased "roughness" of urban areas may be simulated by reducing wind speeds in the lower boundary layer.

4.4.3 Modifications Made to the Model Used for the 1990 Projections

Three fundamental criteria were used to determine which modifications or parameter changes to incorporate in the model for the 1990 projections:

1. Modifications or parameter changes must be physically realistic; thus parameters chosen must be within the range of experimentally measured values.

2. Modifications or parameter changes must be appropriate for use in the planning year 1990.

3. The evaluation of modifications or parameter changes must be based primarily on their effect on the regionally averaged agreement of calculated versus observed values, rather than on agreement for individual stations.

On the basis of these criteria, only changes in the meteorological parameters were adopted in the model. The emission rate-dependent modifications were not appropriate for the seasonal and annual average calculations, and their effects were left to be corrected by the final calibration. The modifications incorporated for the 1990 case were:

1. A half-life of 3 hours was assigned to SO_2 emissions.

2. Vertical spread statistics were adopted from the McElroy-Pooler study in St. Louis[6].

3. Velocities for use in the computation of plume rise were computed from a power law formula, recognizing the increase of velocity above the surface level.

4.4.4 Final Calibration of the Model

With the parameter modifications implemented in the model, final validation runs were made for the five receptors for the winter, summer and annual cases. The ratio of the predicted to measured concentrations was then calculated for each station, for each season, and for each pollutant for which data were obtained. For the sites used in the validation, these ratios were used as simple calibration factors. For estimation of concentrations at any other location within the planning region, averages of the calibration factors for the entire region were derived and used for each pollutant.

5. OPERATIONAL FEATURES OF THE AQUIP SYSTEM SOFTWARE

5.1 Overview of the AQUIP System Software

The software components of the AQUIP System provide the analytical tools necessary to undertake the air pollution impact of land use plans. The AQUIP software system makes use of input data sets and model parameter data sets, performs computations using four basic computer programs, and provides tabular and graphical outputs of the results. The logical relationships among these elements of the software are shown in the summary flow chart of Figure 5. Data sets are shown as rectangles, computation steps as circles, and printed output as document symbols. In addition, each element is identified by a code made up of a generic letter followed by a number. The latter prefixes and their meanings are:

I - Input data set, prepared by the system user.

M - Model parameter data set, established initially for the study conditions, and modified only as necessary for updates to the model.

P - Computation step involving one of the four basic computer programs.

C - Computed data set formed as an output of one computation step and used as an input to another.

T - Tabulated outputs (or line printer graphics) delivered to the system user.

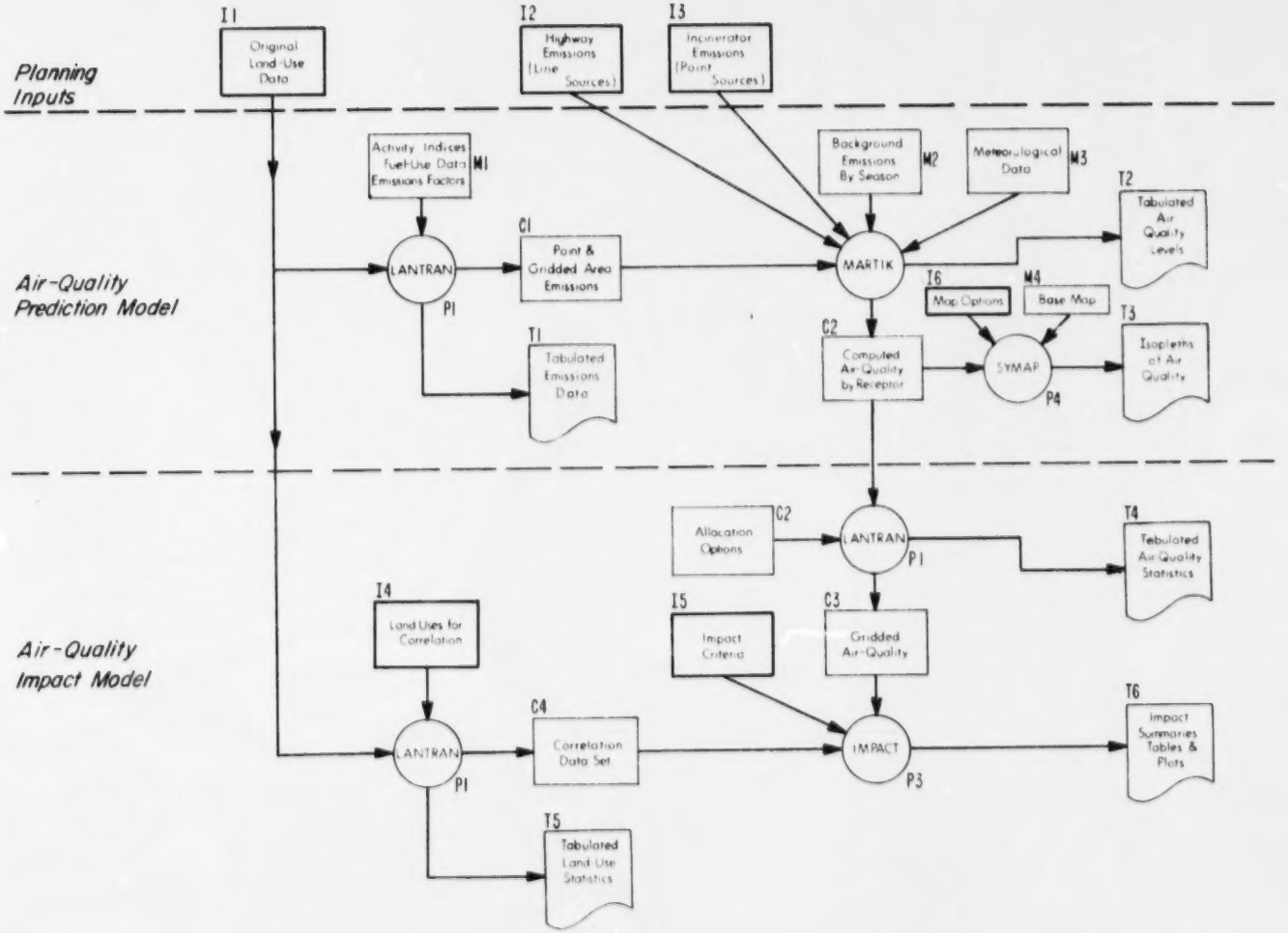

Figure 5 AQUIP Software System - Summary of Programs, Data Sets, and Information Flows

This identification procedure is used consistently in this section to enable each element of the AQUIP System to be identified and described. In the following paragraphs the four principal computer programs, which determine the overall operating modes and capabilities of the AQUIP System, are discussed in terms of their specific functions, information flows, data format requirements and run options. In addition, several of the important points of interaction between the planner and the model are described.

5.2 Planning Inputs

The objective of the AQUIP System is to test hypothetical configurations of land uses with repect to their impact upon air quality, and to compare and rank them in relation to one another. The primary input to the AQUIP System is therefore a numerical description of a land use plan. Thus, the first element of the AQUIP software system involves the preparation of land use data. Ultimately, the necessary form of the numerical description of the plan is an emissions inventory for input to the ERT/MARTIK diffusion modeling program. Although the data could be prepared in this form to begin with, it is more practical (particularly in view of the complex nature of the emissions projection process) to prepare the inputs in a form as close as possible to the actual planning variables associated with the plan.

For this reason, original land use data are prepared by the user, working directly from a map of the study region. Land use activities are defined, classified, and indicated as point, line, or area "figures" on the map. Area zones are represented as polygons (i.e., bounded by straight-line segments); and highways are represented as connected straight-line segments. Other

activities that ultimately can be represented as point emission sources (e.g., power plants) are also indicated.

Each activity region or figure is assigned a set of activity codes and values that define the procedures used to compute its emissions. For example, a residential region could be represented as a polygon and assigned a "residential classification code" together with values that determine how it is to be treated in computing emissions. Geographical data for each figure are prepared by coding the coordinates of the vertices of its boundaries. These data are then incorporated into the "original land use data" (I-1), together with the codes and values. The result is a data set describing a land use plan in terms of planning variables to which the emissions-projection methodologies (in the LANTRAN computer program) can be applied. The activity codes used consist of a letter followed by two digits. For example, the letter R was used for residential with the first digit relating to the appropriate land use plan and the second to the density of a particular residential zone. Other types of land uses were treated in a similar manner. For manufacturing, however, the letter S followed by the appropriate 2-digit SIC code was used.

Highways and some types of point source activities (such as power plants and incinerators) are treated separately. In the case of the highway data, the geographical coordinates of the end-points of the various links are coded, together with emissions derived by application of emissions factors to traffic volume projections. These data become the "highway emissions" data set (I-2), used as a direct input to the ERT/MARTIK diffusion modeling program.

Similarly, the geographical coordinates which locate power plants, incinerators, or other point-sources are coded together with direct emission

rates and stack parameters determined separately for each source. These data become the "point-source" data set (I-3), used as a direct input to the diffusion model.

5.3 Air Quality Prediction Model

Having prepared data sets representing the original land use data as described above, the computation of emissions from the coded area zone activity data is performed by the LANTRAN program. The computation involves the allocation of data defined on the set of figures to a grid-cell system in order to represent the large number of small discrete sources as area sources. Because the diffusion model requires rectangular (not necessarily square) area sources, LANTRAN transforms figure-based data to grid-based data. In principle, it is emissions defined on the figures that are allocated by LANTRAN; in fact, the program performs one additional step: land use data are first converted to emissions data, which are then allocated to the grid system. Some of the emissions data are, however, represented in the output as points, rather than as gridded area sources because: (1) certain activities generate point source emissions (such as schools or hosptials within residential areas); and (2) individual discrete sources with emissions greater than some threshold must be considered separately. The result of this computation step is the "point and gridded area source" data set (C-1) in the form of card decks (corresponding to each averaging period) for use as a direct input to the diffusion model. LANTRAN also produces tabulated output describing the emissions characteristics of the input data, and graphical displays of emission rates by pollutant as allocated to the chosen grid system.

The next step involves the use of the ERT/MARTIK air quality prediction model. This model performs the essential transition from the emissions

generated by a particular land use plan to the air quality concentrations associated with the plan. The emissions inventory data sets, (I-2), (I-3) and C-1) as described above, are input to the MARTIK program, along with the model data sets that define the receptor sites at which concentrations are to be computed, the meteorological parameters, and the emissions assigned to the "background" region, i.e., the region outside the plan boundaries. The result of this step is a set of computed concentrations for each pollutant, at each of the desired receptor sites. The MARTIK calculations define the "computed air quality" for each appropriate seasonal or annual time-averaging period. The results are printed as a tabulated output (T-2) and are passed to additional AQUIP operations as the data set (C-2).

The final step involved in the AQUIP air quality prediction model is the plotting of computed air pollution concentrations using the SYMAP program. The result of a SYMAP plotting run is a graphical display (T-3) of the study area, with printer-generated shading proportional to the computed concentration at each point. An example of this contour map is shown in Figure 6. The data used as input to the program is the set of receptor "values" computed by MARTIK and output as the data set (C-2). Data prepared by the system user consists of options that select the pollutant to be displayed, and that control the appearance of the output map.

5.4 Air Quality Impact Model

The initial step in the use of the air quality impact model is the preparation of land use and other data for correlation with air quality data. In this step, subsets of the original land use data are selected and processed for correlation with the predicted air quality associated with the plan. The computations involved in this process are performed by the LANTRAN program. Operation of the program is similar to its use in the preparation of emis-

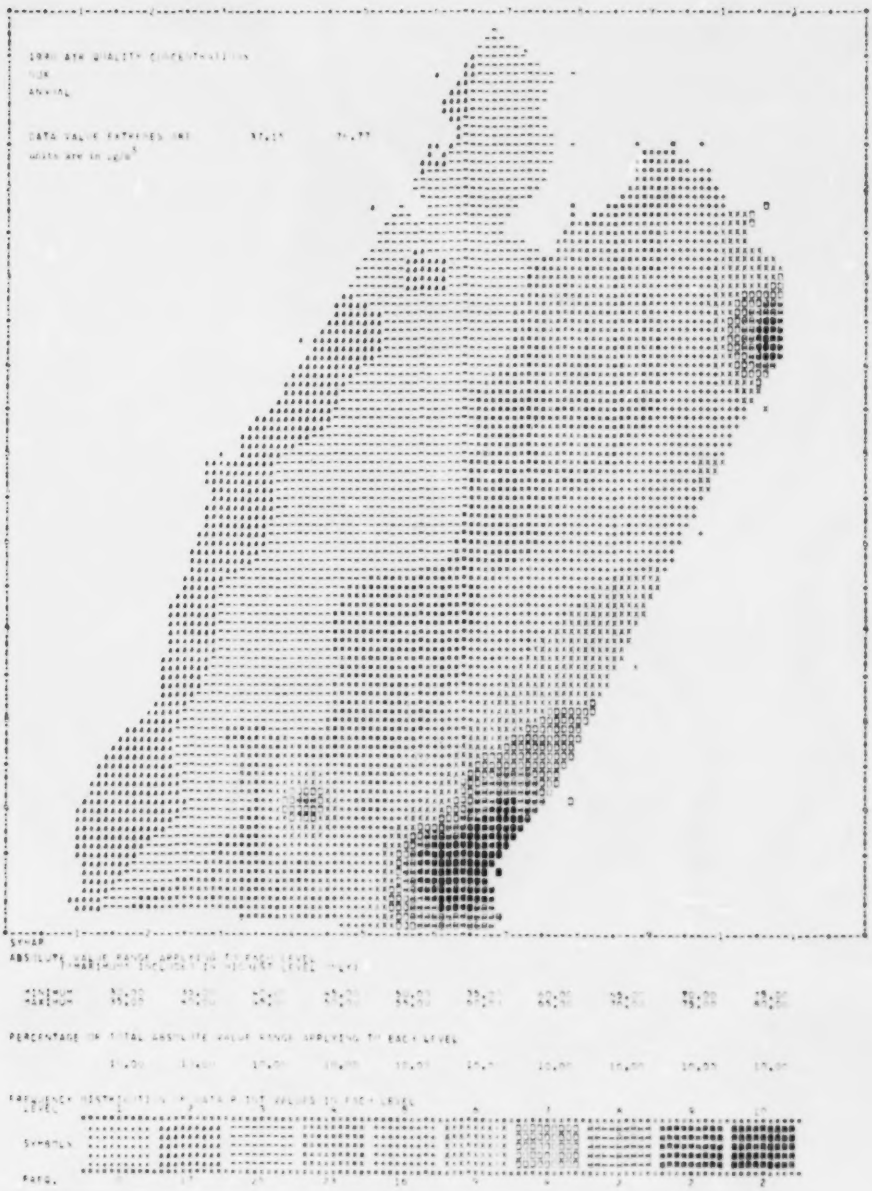

Figure 6 Example of SYMAP Computer-Generated Air Quality Contour Map

sions data, except that, instead of emissions defined on a set of land use figures, the quantities allocated are variables such as population density and acres of industrial land use. The result of this step is a data set, referred to as the "correlation data set" (C-4), which is created in the form of an output card deck for input to the IMPACT program. In addition, grid plots of each selected land use can be generated.

The result of a diffusion analysis with the ERT/MARTIK program is a set of concentrations computed for the given receptor sites. However, in order to perform the impact analysis, these results must be converted to mean air quality defined on the grid system chosen for analysis. This conversion is performed by the LANTRAN program, which constructs a mean surface through the receptor points and then assigns to each cell of the grid system the surface value at the cell center. This step is necessary because there is no direct relationship between the spacing or distribution of receptor points and the grid system used in the impact analysis model. The computation step may be performed routinely, with no interaction from the user (other than to define the grid system). The results of the air quality prediction model calculations are contained in the data set (C-2) produced by the ERT/MARTIK program and used as an input to LANTRAN. The tabulated output from LANTRAN lists the concentrations as allocated to each grid cell, and a corresponding graphical output can be generated if desired. Output from the program is the gridded air quality data set (C-3) and is used as an input to the impact analysis procedures.

The final step in the AQUIP modeling system is the analysis of the air pollution impact of the original land use data. This step brings together the various data sets of the system, such as land use data or concentrations data, for final evaluation and ranking of planning alternatives. The planner

interacts directly with the AQUIP model at this point by defining the criteria by which the plan and its alternatives are to be ranked, and by specifying the desired set of operations to manipulate the data sets. The planner codes these analytical procedures into the IMPACT computer program using a simple "hyper-language". Any number of gridded data sets may be brought together, and any number of new data sets can be created. In general, the specified analytical operations produce quantitative information for each cell of the grid system. The results are tabulated and can be presented graphically as grid plots. Examples of the types of analyses which may be performed using the IMPACT program include the comparison of projected air quality with air quality standards, the correlation of air quality data with land use data, the display of specific land use data (for example, the location of critical receptors), the calculation of impact parameters, and the calculation of plan ranking indices.

6. EVALUATION AND RANKING OF THE HACKENSACK MEADOWLANDS LAND USE PLANS

6.1 General Air Quality Criteria for Plan Evaluation

The basic objective of this analysis was to demonstrate the AQUIP System methodologies for considering air pollution in the planning process through the direct application of such methodologies to the planning alternatives developed for the Meadowlands. Regional air quality concentrations for total suspended particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_X) were analyzed in terms of annual averages and summer and winter seasonal averages. The analysis also included the influence of sources outside the Hackensack Meadowlard, i.e., background sources, on air quality within the planning region.

The evaluation of the land use plans was based primarily on the considerations of:

1. Compliance with ambient air quality standards.
2. The influence of background concentrations on total air quality within each plan.
3. Average regional air quality concentration levels.
4. The percent variation in total air quality among the plans on a pollutant by pollutant basis.
5. Average exposures of critical receptors and land use categories to pollutant concentrations.

In order to assess compliance with standards, the calculated annual

average pollutant concentrations were compared with corresponding annual average standards, or in cases where such standards do not exist, with equivalent values of ambient air quality standards extrapolated to annual time-averaging periods. The standards (or their extrapolated equivalents) used in this analysis are summarized in Table 1 along with an indication of the method of derivation.

A qualitative evaluation of plans was carried out by means of a visual examination of air quality contours and the subjective correlation of such contours with the land use categories of each plan. A quantitative analysis and evaluation of plans was carried out by the calculation of quantitative measures of impact. This quantitative evaluation was based primarily on "averaged" impacts (such as average regional concentration levels or average levels of exposure to specific receptors) rather than "integrated" impacts (which are proportional to both average concentration levels and the total number of receptors affected).

In addition to these criteria, the evaluation of the plans was subject to other constraints and general considerations. In particular, the analysis was oriented toward regional effects based on the calculation of mean annual pollutant concentration levels. The analysis considered the effects on regional air quality and on critical receptors resulting primarily from differences among the four plans in: (1) the percent mix of land use categories; (2) the relative locations of land uses; and (3) the relative intensity of land use activities. The direct relationship between pollutant concentrations and impacts such as health effects and socio-economic consequences were not considered. Moreover, the analysis did not consider localized or

TABLE 1

EQUIVALENT ANNUAL AVERAGE AIR QUALITY STANDARDS

Pollutant	Standard(1) ($\mu g/m^3$)	Standard(1) (ppm)	Derivation
TSP	70.1	-- (3)	From N.J. (geometric mean) annual standard(2)
SO_2	53.0	0.02	N. J. annual standard
CO	1425.0	1.25	Extrapolation from Federal 8-hour standard using statistics from N.J. measurements data (2)
HC	160.0	0.24(3)	Federal (secondary) 3-hour standard(4)
NO_X	100.0	0.05(3)	Federal (secondary) annual standard

(1) Annual arithmetic mean, never to be exceeded

(2) Extrapolations based on use of Larsen Model. (Larsen, R.I. "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards", Office of Air Programs Publication. No. AP-89, EPA, Office of Air Programs, Research Triangle Park, N.C., 1971.)

(3) Conversion to ppm not strictly possible without specifying composition of pollutant: HC is based on CH_4; NO_X is based on NO_2.

(4) Extrapolation of 3-hour (6 to 9 AM) standard to an annual standard not considered valid.

microscale impacts, nor the interrelationship between air pollution effects and other environmental concerns such as water quality or solid waste disposal.

6.2 Summary of Land Use Plan Characteristics

The four alternative 1990 Comprehensive Land Use Plans for the Hackensack Meadowlands District analyzed in this study are designated as:

Plan 1 - The Master Plan[2]

Plan 1A - Self-Supporting New Town

Plan 1B - Expansion of New York City Urban Core

Plan 1C - Trend Development Based on Current Zoning

These plans are shown in Figures 7 through 10. The basic data and assumptions concerning the land uses for each of the plans were supplied by the HMDC and were processed and coded for input to the AQUIP System. The resultant percent mix of land use categories, together with population and traffic projections for the different plans are summarized in Table 2.

The four plans show significant differences both in the relative location of land uses and in the percent mix of land use categories. Plan 1, the Master Plan, is characterized by a large amount of open space (31% including open water), a relatively low population (148,000), and a broad mix of industrial and commercial activities. The dominant feature of the plan is the expansive area along the Hackensack River devoted to parks and conservation land. Only 6% of the total area is allocated to residential area, which consists mostly of very high density island high-rise apartments and parkside residential areas located at points within this open space region.

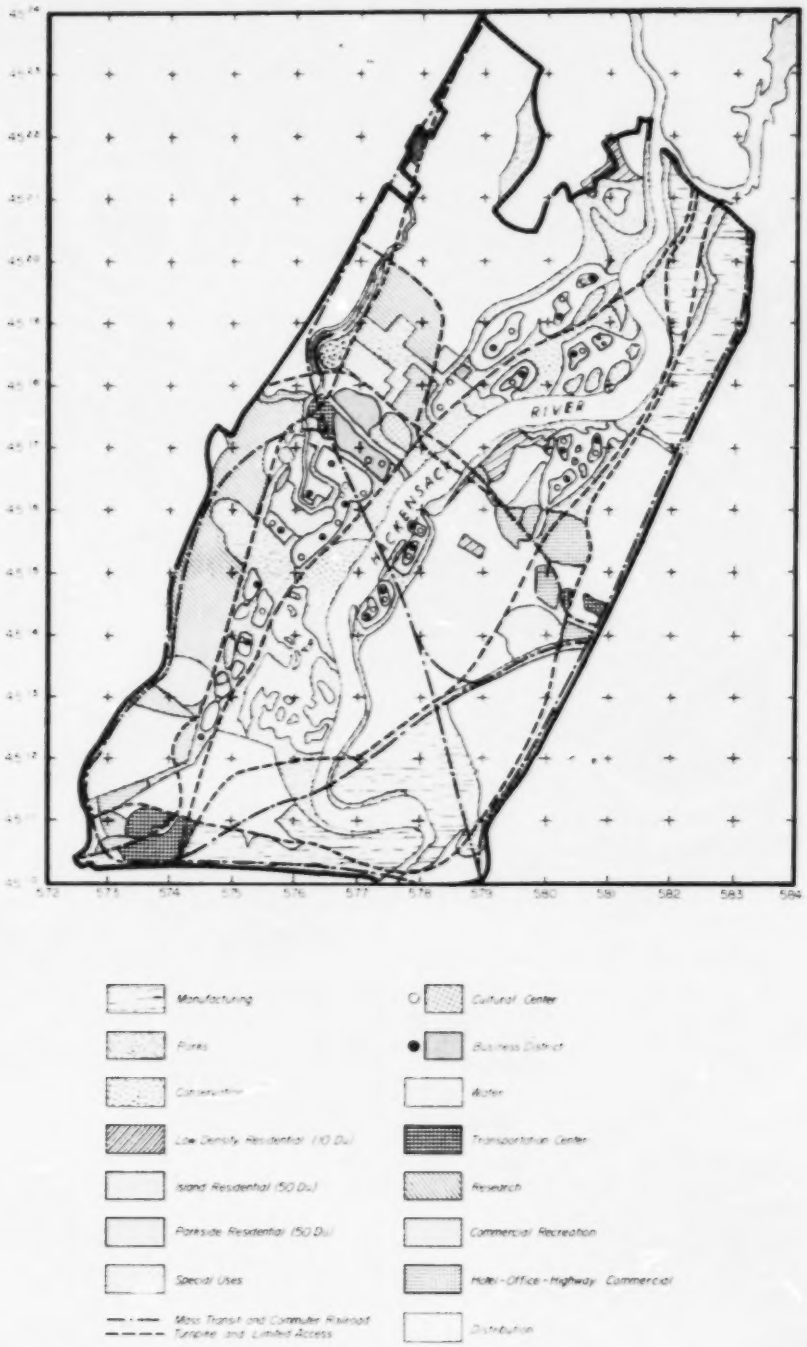

Figure 7 Alternative Meadowlands Land Use Plan No. 1--The Master Plan

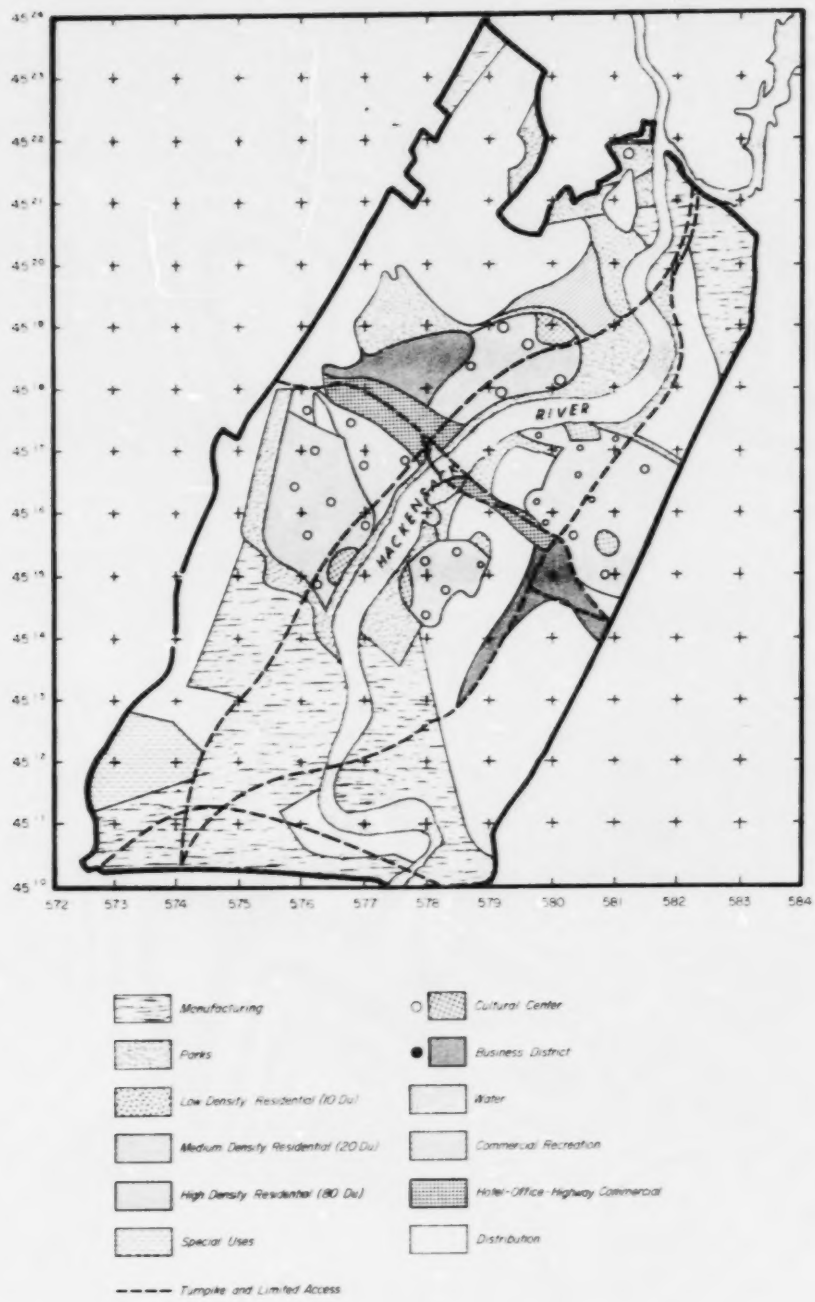

Figure 8 Alternative Meadowlands Land Use Plan No. 1A--Self-Supporting New Town

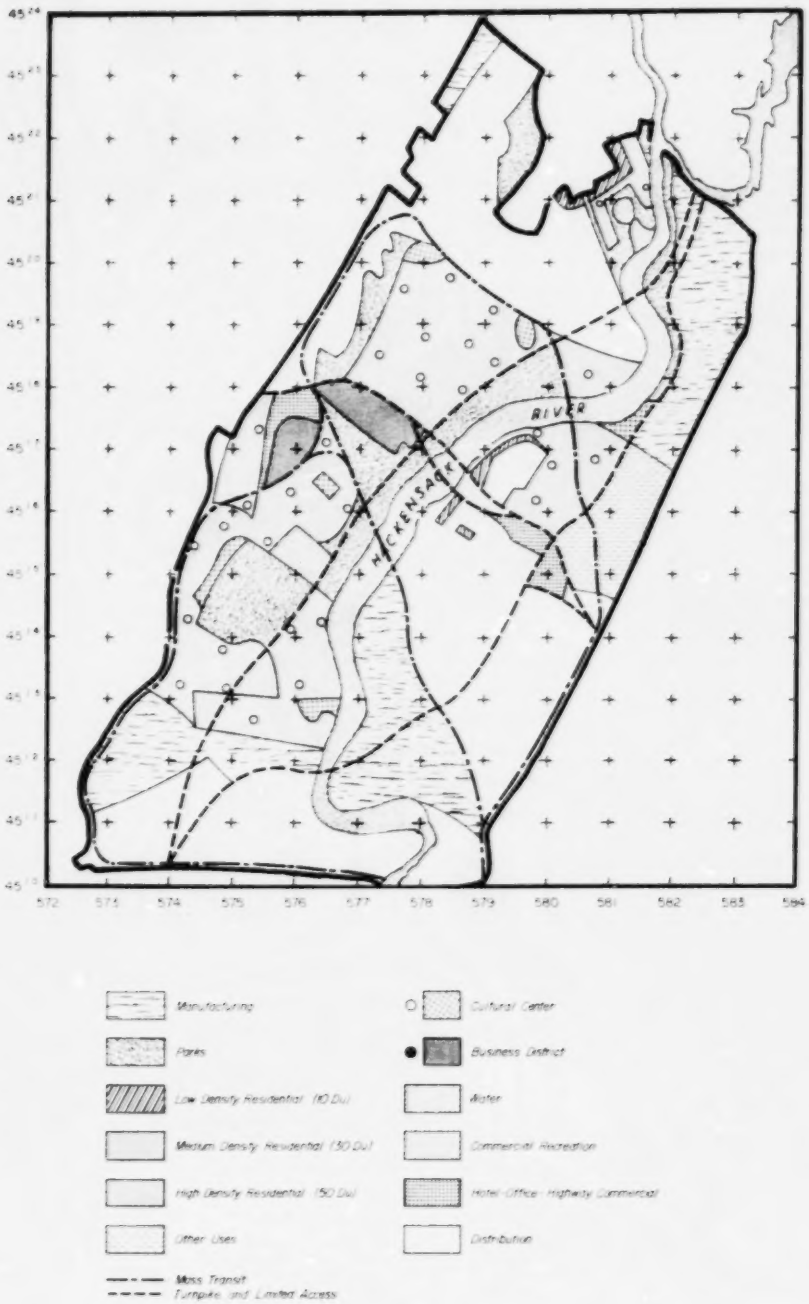

Figure 9 Alternative Meadowlands Land Use Plan No. 1B--
Expansion of New York City Urban Core

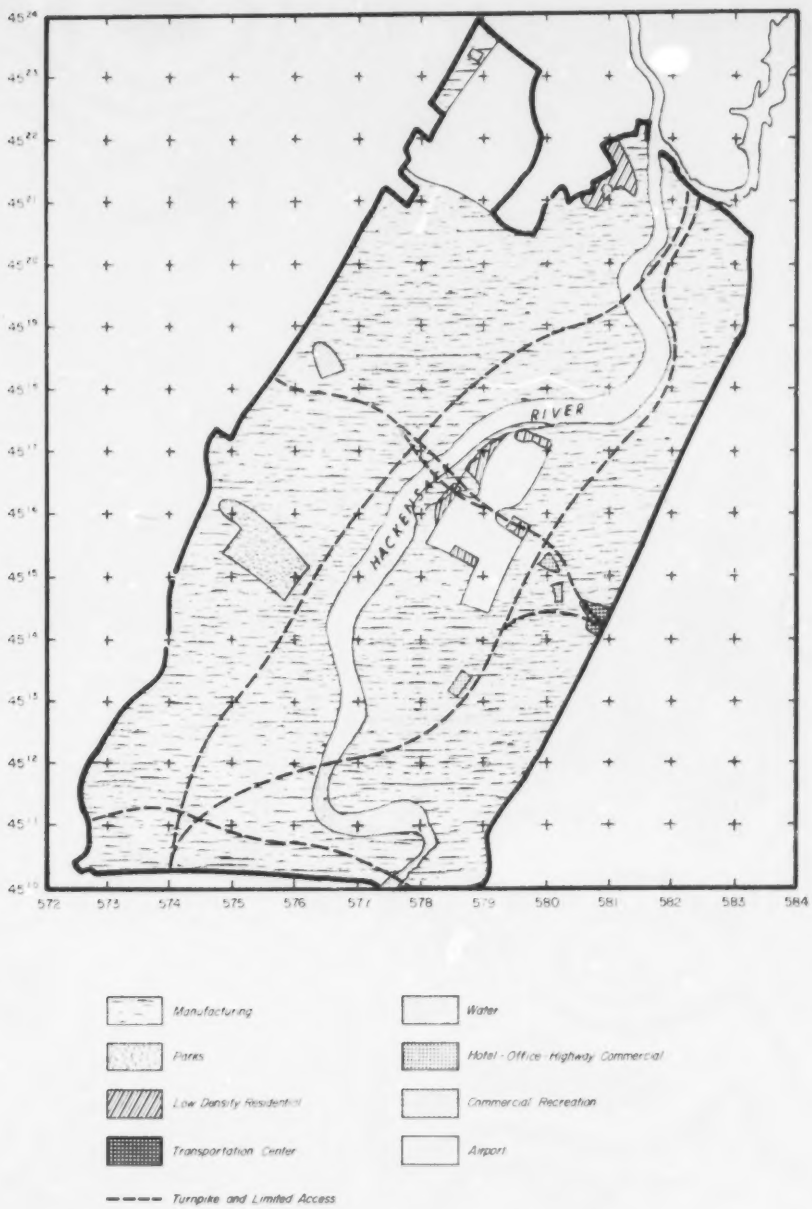

Figure 10 Alternative Meadowlands Land Use Plan No. 1C--
Trend Development Based on Current Zoning

TABLE 2

SUMMARY OF LAND USE INFORMATION FOR
HACKENSACK MEADOWLANDS PLANS

Land Use Categories	Percent of Total Plan Area			
	Plan: 1	1A	1B	1C
Residential[1]				
10 DU/AC (dwelling units/acre)	1	2	1	1
20 DU/AC		7		
30 DU/AC			5	
50 DU/AC	5		15	
80 DU/AC		8		
TOTAL	6	17	21	1
Commercial & Industrial[1]				
Commercial	4	4	3	1
Manufacturing (light & heavy)	8	14	15	18
Research	8	0	0	0
Distribution	22	19	22	50
Special Use	1	0	0	0
Airport & Transportation Center	5	4	4	4
TOTAL	48	41	44	73
Open Space[1]				
Water	11	7	7	7
Parks & Conservation	20	11	11	2
TOTAL	31	18	18	9
Other[1]				
Highway & Railroad	12	21	15	14
Special	3	3	2	3
TOTAL	15	24	17	17
TOTAL LAND AREA (19,600 acres)	100%	100%	100%	100%
Total Population[2]	147,604	408,080	469,788	8,161
Total Students[2]	25,758	59,689	114,647	0
Total VMT/Year ($x10^6$)[3]	1,040	1,405	1,515	970

(1) As coded from land use maps -- figures used may not correspond exactly with original estimates given by the HMDC.

(2) As computed from land use data.

(3) Totals include the regional network traffic of $930x10^6$ VMT: in addition, $4x10^6$ hrs. idling/yr. are assumed for parking lots for all plans.

The business and commercial activities are located primarily in the central region of the meadowlands west of the Hackensack River. Industrial activities (i.e., manufacturing, 8%, and distribution, 22%) are largely located in the eastern half of the region, although a sizable area (8%) devoted to research industry is located along the western border of the district. Plan 1 also includes various modes of public transportation, including novel means of waterborne transit, as well as new roadways. Arterials servicing the high density residential areas are located to minimize local surface street traffic.

In contrast, Plan 1A, the Self-Contained New Town, is characterized by a higher population (408,000), greater residential area (17%), and less open space (18%). The open space areas are predominantly located on the fringes of residential areas, acting as buffers to surrounding industrial areas. The primary commercial and industrial land use activities are devoted to manufacturing (14%) and distribution (19%). A significant feature of this plan is that essentially all of the population is located within the central portion of the planning region, spread from west to east, with low density areas in the west and extremely high density areas in the east. Furthermore, nearly all manufacturing activity is located in the southern portion of the planning region, while distribution activities are located in both the eastern portion of the region and in the vicinity of Teterboro airport. Characteristically, major access roadways are on the fringe of the residential areas to reduce surface street traffic. Since it is assumed that employment will be served mostly by local population, and that most of the journey to work trips will be served by the local roadway system, a significantly high percentage of land use is devoted to highways (21%). Moreover, no rapid transit

is indicated in the plan. Consequently, the total miles of vehicular traffic projected for this plan (1.4 billion VMT/year) reflects both the higher population and the increased levels of local traffic.

Plan 1B, the New York City Urban Core Expansion, is nearly identical to Plan 1A in percent mix of land use categories but has a significantly different location of these land use activities within the planning region. The primary difference is that nearly all residential area (21%) is located in the western part of the district; and while Plan 1A has areas of low and extremely high density dwelling units, Plan 1B has mostly intermediate density areas. The eastern portion of the Meadowlands is predominantly devoted to commercial and industrial land use activities. Manufacturing (15%) is widely dispersed, being located mostly in the southern and northeastern portions of the district. Distribution (22%) is similarly dispersed widely throughout the region. Again, as in Plan 1A, open space is used as a buffer between residential and industrial areas, and to expand the open space along the river. Plan 1B has the largest projected population (nearly 470,000) and the largest projected amount of traffic (over 1.5 billion VMT/year) of the four plans. Because of its planned close relationship to the New York City urban core, this plan also contains a substantial amount of rapid transit and commuter railroads in addition to new arterials to serve the residential areas.

Plan 1C, the Trending of Current Zoning, is significantly different from the other three plans in the percent mix of land uses. It contains less than 1% residential area (to serve a projected population of approximately 8,000), while having little open space (9%) except for that associated with open water. Most of the region is devoted to commercial and industrial activities (73%), primarily distribution (50%). Industrial areas (18%) were

allocated by the HMDC to 10-acre plots. Furthermore, because of the low population, this plan also has the lowest projected traffic (0.97 billion VMT/year), reflecting primarily the regional network traffic.

6.3 Results of the Air Quality Analysis

The principal results of the analysis, evaluation and ranking of these plans are summarized in the following paragraphs.

1. Annual average ambient air quality standards are met for the 1990 time period in all four plans for the Hackensack Meadowlands region for three pollutants: SO_2, CO, and NO_X. Annual average ambient air quality standards are exceeded for 1990 in all four plans for two pollutants: TSP and HC. The analysis also indicates that the projected background concentration levels for both TSP and HC exceed ambient air quality standards in 1990.

2. Analysis of the air quality of plans on the basis of individual pollutants indicates that:

   a. For TSP, maximum concentrations exceed the standard in all four plans by a factor of approximately 2.5. Thus, air quality for TSP is a critical problem and must be of concern to the planner.

   b. For SO_2, maximum concentrations are on the order of 55 to 60% of the standard. Furthermore, the variation among plans in impact on average regional air quality is less than 15%. Thus air quality for SO_2 is not a major problem and the planner can be neutral (relative to regional air quality criteria) in choosing among the four plans.

c. Air quality for CO is of major concern within Plan 1B, for which the maximum concentration is approximately 90% of the standard. Because maximum concentrations are less than 70% of the standard and variation in impact on average regional air quality is approximately 4%, the planner can be neutral in choosing among the remaining three plans.

d. For HC, maximum concentrations exceed the standard in all four plans by a factor of approximately 12. This is a critical problem and must be of concern to the planner.

e. For NO_x, maximum concentrations are on the order of 65% of the standard, and variation in impact on average regional air quality is approximately 7%. Thus, air quality for NO_x is not a major problem and the planner can be neutral in choosing among the four plans.

3. Analysis of the total regional air pollutant concentration levels and spatial patterns for the four alternative plans shows a significant variation (up to 15%) among plans for all pollutants except hydrocarbons. The quantitative ranking of plans in terms of the multipollutant impact on total regional air quality indicates that Plan 1 is best (that is, produces least average regional concentration levels), followed by Plans 1B, 1A and 1C, respectively.

4. The corresponding analysis of the impact resulting from regional air quality concentration levels and spatial patterns on sensitive categories of land uses and receptors (primarily population) shows a significant variation in impact among the four alternative land use plans. A quantitative ranking of the alternative plans based on consideration of a number

of impact measures indicates that Plan 1 is best (that is, has the least average exposure to the specified classes of receptors), followed by Plans 1B, 1A, and 1C, respectively.

5. Background air quality levels represent a major influence on total air quality levels within the Hackensack Meadowlands planning region. Background air quality accounts for between 65% and 99% of total concentration levels within the planning region and completely dominates the spatial patterns of total air quality concentrations. The background air quality contours for all pollutants show a north-south orientation with concentrations increasing from west to east. This pattern of concentrations shows both the strong influence of pollution from the New York City urban core on Hackensack Meadowlands air quality levels. Because of these factors, a significant spatial variation in background air quality levels occurs over the Hackensack Meadowlands region. Consequently, the relative location of land use activities becomes a significant factor in minimizing the contribution of the specific plan to regional air quality levels and in minimizing the impact of the resultant regional air quality levels on specific receptors and land use categories.

6. Because background concentrations represent such a high percentage of total air quality within the Meadowlands for any given plan, the resultant variation among plans in total air quality necessarily will be small. For example the maximum observed variations among the four plans in average regional air quality occurs for SO_2 and is less than 15%. As a consequence land use planning may be regarded as an ineffective means for abatement of regional air pollution in the vicinity of major urbanized areas unless

the planning region is sufficiently large that "background" concentration levels represent only a small percentage (for example, less than 50%) of total air quality levels.

7. Analysis of the impact resulting from the alternative land use plans on regional air pollutant concentration levels and spatial patterns shows significant variations among plans due to: (1) the percent mix of land use categories; (2) the relative location of land use categories; and (3) the relative density or intensity of land use activities. The observed variations in regional air pollutant concentration levels and spatial patterns are found to be extremely sensitive to the percent mix of manufacturing and transportation related land use activities. Manufacturing influences primarily TSP, SO_2 and NO_X concentrations, while transportation activities influence the CO concentrations. As a consequence, these land use categories should be located within a plan relative to the spatial patterns of background concentration levels in order to minimize net impact on total regional air quality levels.

8. In the Hackensack Meadowlands planning region, all land use activities other than manufacturing and transportation have a negligible impact on regional air quality levels and spatial patterns and therefore can be located within a particular plan rather arbitrarily to provide minimum impact to specific critical receptors and land use categories. Because the degree of impact on critical receptors is especially sensitive to the relative location of the receptors within the plan, the relative location of critical receptors and land use categories represents an extremely important consideration in the formulation and evaluation of land use plans. For example, it is observed that those plans which rank best in terms of population exposure have resi-

dential areas predominantly located in the western portions of the Hackensack Meadowlands planning region where concentrations generally are at their lowest levels.

9. Regional air quality is relatively insensitive to the amount of open space within any of the four plans. A direct tradeoff from manufacturing to open space land use for example, would be highly beneficial to regional air quality levels, not because of the addition of open space within the plan, but rather because of the deletion of manufacturing land uses.

10. The analysis of regional scale air quality considerations is not sufficient to assess microscale impacts (that is, variations in concentrations over short distances and short time periods). Consequently, caution is urged in interpreting results of regional air quality impact analyses. Such analyses will indicate which choice of a land use plan minimizes the impact on regional air quality levels and on critical receptors, but may not indicate the existence of, nor provide a solution to microscale impact problems.

7. PLANNING GUIDELINES

7.1 Introduction

A set of guidelines that can be generally applied to the land use and transportation planning process for the consideration of air pollution were derived from the results of the Hackensack Meadowlands air pollution study. Consequently, these guidelines should be applied to other planning situations only for the consideration of regional scale air quality.

Furthermore, because these guidelines are necessarily based on the specific plan characteristics and assumptions for the Meadowlands, some of the quantitative conclusions tend to be less generally applicable to other plans and planning situations. Most of the guidelines, however, are given in the form of qualitative statements of broadly applicable results.

The resultant planning guidelines describe the basic relationships between air pollution considerations and their impact on land use planning in three areas. The first is background air quality, which is shown to be of paramount concern in plan design, especially in urban regions. The second is the effect of the primary plan design factors that influence regional air pollutant concentrations and spatial patterns: (1) the mix of land use categories; (2) the location of land use categories within the planning region; and (3) the intensity of land use activities. Third are the topography and meteorology of the region, which should play an important part in the consideration of air pollution by the planner.

7.2 Effect of Background Sources on Air Quality

If the background levels of pollution are high within a planning area, as is usually the case in urban regions, then the potential air pollution resulting from the planning area by itself may be only a small percent of the total air pollution. As a result, land use planning may not be an effective means of reducing regional air pollution levels. However, because the actual concentrations resulting from the plan itself may be large, selection of a land use plan to minimize air pollution levels in the planning area is critically important.

If the spatial variations in background concentration patterns are significant, then it is essential to locate carefully land use activities relative to such concentration patterns:

1. To meet ambient air quality standards.
2. To reduce the net regional pollutant concentrations.
3. To reduce the net impact of regional air pollution on critical receptors, such as elementary schools, parks, playgrounds, nursing homes, and hospitals.

Low background pollutant concentrations within a planning area may occur in two ways. First, the planning area may be located within a non-urbanized or non-industrialized area; and secondly, the planning area itself may encompass a sufficiently large portion of the urban region so that the relative influence of background concentrations is low. The result, in either case, is that the percent variation among alternative land use plans may be relatively large. Under such circumstances, land use planning can be effective in reducing regional pollutant concentration levels. From an alternative viewpoint, in regions having low background levels the planner

has a greater degree of freedom in plan design to consider factors other than air pollution because potentially the region can tolerate larger pollutant levels from the plan without exceeding standards. Therefore, air pollution should be an important consideration in the land use planning process for regions having low background concentration levels.

As a consequence of observations based on the Meadowlands study it is concluded that:

1. If total air pollutant concentration levels do not exceed ambient air quality standards and if variation in impact from alternative plans on total air quality is under 15% (an arbitrary but conservative figure), then the planner can be neutral in his choice of a plan with respect to regional air quality considerations. That is, if necessary, he can give greater weight to planning considerations other than air pollution in the selection of land use plans.

2. If background air pollutant concentration levels represent greater than 60 to 70% of the total concentration levels, then land use planning is not an effective means for the abatement of regional air pollution problems.

3. Where feasible, the extent of the planning region should be chosen such that background concentration levels represent less than 30 to 40% of the total concentration levels in order to assure that land use planning will be an effective means for the abatement of regional air pollution problems.

7.3 Effect of Plan Design Factors on Air Quality

Based on the results of the Hackensack Meadowlands air pollution study, it is concluded that the plan design factors that have primary influence on regional air pollutant concentrations and spatial patterns are the mix, location, and intensity of land use activities.

7.3.1 Mix of Land Uses

The land use category designated as "Manufacturing" has the dominant influence on TSP, SO_2, and NO_x concentration levels and patterns. In fact, the emissions from this land use category are a factor of from 10 to 1000 times greater than those from all other land use categories if examined on a basis of emissions per unit of land area. Motor vehicular traffic is a dominant influence on CO concentration levels and patterns. Over 90% of the CO emissions result from motor vehicle traffic, airport operations, and other transportation-related land use activities.

Consequently, regional air quality is highly sensitive to the amount of manufacturing and transportation-related land use categories and is relatively insensitive to nearly all other land use categories. The relative sensitivity factors for each of the different land use categories are listed in Table 3, which shows the annual emissions per unit land area (or per unit activity where appropriate, such as emissions per VMT for motor vehicular traffic, or emissions per hour of idling for parking lot situations) as derived from planning assumptions specifically for the Meadowlands land use plans. These sensitivities differ by pollutant as well as by land use category.

TABLE 3

SUMMARY OF ESTIMATED 1990 ANNUAL EMISSION RATES
FOR HACKENSACK MEADOWLANDS LAND USE CATEGORIES

Land Use Category	Pollutant Emissions (lb/year/acre)				
	TSP	SO_2	CO	HC	NO_x
Residential[1]					
10 Dwelling units/acre	29	1	30	12	75
20 " " "	180	120	4	54	85
30 " " "	180	120	4	54	85
50 " " "	250	160	5	75	120
80 " " "	200	140	4	63	100
Commercial & Industrial					
Commercial	60	45	1	12	95
Manufacturing					
Light	1100	1100	10	140	850
Heavy	5400	5400	60	900	5400
Research	2	15	1	5	35
Distribution	60	45	1	12	95
Special Use	60	45	1	12	95
Airport[2]	100	1000	3000	350	100
Transport Center	180	130	2	36	300
Cultural Center	45	35	1	9	70
Open Space	0	0	0	0	0
Other[3]	Emission Factors				
Highway ($lb/10^6$ VMT)	700	400	11000	1000	1500
Parking Lots ($lb/10^3$ hrs idling)	4	4	12	3	1

(1) The particular numbers for residential emissions are a function of type of fuel assumed for the Hackensack Meadowlands by building type (single family versus high rise), the size of dwelling units as they vary with density and building type, and the efficiencies of central heating systems in addition to density. For example the numbers for 10 dwelling units/acre for the Meadowlands are radically different from the others because this is the only residential category assumed to be single family and to use natural gas as a fuel.

(2) Assumes 400,000 flights/year from Teterboro Airport, and 700 acre area.

(3) Activities are not specified on basis of emissions/unit area.

It can be concluded on the basis of differences in these sensitivity factors that open space is not a dominant influence on regional air quality levels. Rather, regional air quality is far more sensitive to land use categories having large emission rates. A direct trade off between manufacturing and open space land use, for example, would be highly beneficial to regional air quality levels, not because of the addition of open space within the land use plan, but rather because of the deletion of manufacturing.

7.3.2 Location of Land Uses

The location of land use categories is a second major factor in determining regional air quality patterns except when background concentrations are high relative to those resulting from the plan alone. However, because critical receptors are always exposed to total air quality levels (i.e., plan plus background contributions), the location of land uses within the plan will always have a major influence on receptor impacts, especially if background concentration levels are high and have a significant degree of spatial variation.

Primary attention should be devoted to the location of the dominant land use emission sources within the planning area relative to background concentration levels and patterns (especially where large variations in background levels and patterns occur within the planning region) to assure compliance with appropriate standards. Dispersal of large individual emission sources (e.g., power plants or incinerators) may eliminate localized problems or "hot spots", but will not especially reduce average ground level concentrations throughout a region. Land use categories that are not especially sensitive to the effects of air pollution should be located in regions

of higher background concentration levels in preference to those land use categories that are more sensitive to the effects of air pollution. In general, the latter should be located in regions of lower background concentrations to the greatest extent possible.

Land uses other than those few having very high emission rates can be located rather arbitrarily within the planning region without significantly affecting the air quality concentration levels and patterns on a regional scale. Thus, in general, the planner can locate critical receptors within the plan without causing any significant impact on regional air quality levels in order to reduce the air pollution impact on these critical receptors and land use activities.

Land use activities are usually interrelated and cannot be located independently nor without the consideration of emissions associated with such interrelated activities. For example, although residential areas, commercial areas, and other centers of social and occupational activity generally produce very low emissions directly, the placement of such activities will generate motor vehicle traffic, which in turn will influence concentration levels and patterns for CO and other automobile-related pollutants.

Finally, the location of land use categories, particularly those having large emissions, can also benefit regional air quality concentration levels. By dispersing such land use activities throughout the plan (rather than concentrating such activities within a single region) lower average regional air pollutant concentration levels can be achieved for planning alternatives having similar mixes of land use categories. In effect, such dispersal of large emission sources results in a larger effective mixing volume for the pollutants, leading to lower average regional concentration levels.

7.3.3 Intensity of Land Use

Intensity of land use, the third important plan design factor, refers either to the fraction of acres of land use per acre of land area, or to the actual density of land use activities such as population density or residential dwelling units per acre.

For major emission sources intensity can have a very significant impact on regional air quality concentration levels, since air quality concentrations are proportional to the total amount of manufacturing activity or to total vehicle trip miles. The data in Table 3 again indicates the sensitivity of regional air quality to levels of land use intensity. In general, intensity of land use will have a minor impact on regional air quality in comparison to the impact of the mix and location of land use categories. The primary impact of variations in land use intensity will occur in terms of the impact of pollutant levels on specific receptors primarily as a result of limiting the number of receptors effected within the plan or within a specific region of the plan.

7.4 Effects of Topography and Meteorology on Air Quality

Local topography and meteorological conditions have a major influence upon air quality patterns. With careful consideration of these factors the planner can enhance air quality within a region through appropriate plan designs.

7.4.1 Topography

Table 4 summarizes some of the principal effects of topography upon air quality patterns. Air quality patterns in planning areas that are relatively flat and homogeneous, such as the Hackensack Meadowlands, are not significantly influenced by the conditions described in this table.

The local variation in surface roughness associated with development plans (i.e., buildings, roadway rights-of-way, etc.) will be more important than natural topography in determining microscale features in air quality patterns. Thus, the results of the Meadowlands study are generally applicable to other planning areas that have relatively flat and homogeneous terrain. On the other hand, the results of the present study are not considered to be representative of regions having highly variable or unusual terrain.

7.4.2 Meteorological Effects

The four basic meteorological effects upon air quality levels are: (1) advection, related to wind speed and direction; (2) diffusion, related to atmospheric turbulence levels; (3) transformation of pollutants, related to humidity, available sunlight and the presence of other substances; and (4) removal of pollutants, related to pollutant characteristics, precipitation and other factors not yet well understood.

In regional scale planning studies where the long time average concentration profiles (i.e., seasonal and annual averages) are of primary concern, the most important meteorological information is contained in the long period climatological records available for the region. For evaluation of seasonal and annual averages the following review of climatological data is suggested:

TABLE 4

PRINCIPAL EFFECTS OF TOPOGRAPHY UPON AIR QUALITY PATTERNS

Topographic Feature	Effects
1. Elevated regions	a. Increased wind speed (and increased ventilation) over hill tops. b. Occasional impacting of elevated plumes on ground level.
2. Deep valleys	a. Channeling of wind flow along the valley axis, resulting in higher average concentrations in the valley. b. Development of stable, drainage winds during calm, nighttime conditions, resulting in higher concentrations along the valley floor.
3. Undulating regions	a. Increased atmospheric turbulence near the ground level during times of moderate or strong winds. This results in lower pollutant concentrations at locations near sources. b. Accumulation of pollutants in low spots during calm, nighttime conditions (i.e., localized drainage wind conditions).
4. Regions of tree cover	a. Enhanced turbulence near the ground during moderate or strong winds, resulting in lower concentrations for locations near sources. b. In fully covered regions, blockage of elevated plumes, resulting in lower concentrations at ground level.
5. Bodies of water	a. Increased moisture content in the local atmosphere, favoring fog formation at low-lying spots, and affecting the removal rate of SO_2 and other pollutants from the atmosphere. b. For larger bodies of water, formation of local circulation (lake and sea breezes) which can cause ground level fumigation on the landward side of sources, during sunny daytime conditions.

1. Stability Wind Rose Data

This information is used for the model input data relative to distributions of wind speed, wind direction and stability categories. The climatological data should be representative of the planning area. In situations where the terrain is significantly different in the planning area compared to the nearest meteorological observing station, the climatological records must be used with reservation, or must be modified to reflect conditions known to exist in the planning area.

2. Mixing Depth Climatology

Holzworth[7] has summarized mixing depth information for all of the contiguous United States. Low mixing depths, e.g., daytime depths less than 500 meters, result in elevated concentration levels throughout the planning region, because the normal vertical diffusion of pollutants is inhibited. Most air pollution episodes occur during periods when low mixing depths persist for two or more days. Although such episodes can occur during any time of the year, the frequency of such episodes is greatest during the autumn months in the northeastern coastal regions of the United States.

Although the principal focus of these guidelines is the regional scale, some general comments about localized air pollution impact can be added. Two important cases are: (1) large, isolated sources with tall stacks; and (2) ground level sources, such as highways.

Large volume sources with tall stacks will produce maximum ground level concentrations at distances of from 10 to 40 stack heights downwind. The effective range of significant impact from such a stack depends on stack height, mixing depth, wind speed, and other meteorological conditions, but for general plan estimation purposes the effective radius of influence can be considered to be approximately three times the distance between the source and the point of maximum ground level concentration.

In the case of highways, emissions occur at near-ground level, and maximum concentrations occur in the immediate vicinity of the roadway. Maximum concentrations may occur either within the roadway (especially for wide roadways) or within the first 20 meters from the edge of the roadway. The rate of decrease in concentration levels is large for such sources. Concentrations from roadways commonly are reduced to 10% of maximum concentration levels (in the absence of background), within a distance of 100 to 500 meters from the roadway edge, depending largely on local structures and terrain. Therefore buffer zones (where no other sources occur and where public access is limited) are particularly effective for minimizing impact from such sources.

The consideration of meteorology is critically important in the analysis of air pollution consequences of land use plans. Although generally speaking lower total emissions for a plan will result in lower total concentrations within the planning region, it is important to evaluate and rank plans on the basis of pollutant concentrations rather than emissions for several reasons:

1. Air quality standards and health effects are related to concentration levels.

2. Meteorological conditions are critical in determining the capacity of a region to assimilate local source emissions (that is, to determine conditions under which planned land use developments will exceed or comply with national ambient air quality standards).

3. Meteorology is critical in determining levels of background pollutant concentration transported into and out of the planning region.

7.5 Limitations of Regional Air Quality Considerations

These suggested planning guidelines are convenient for making broad planning estimates; for example, in developing basic concepts for plan design. It is totally unwarranted, however, to assume that these guidelines are sufficiently accurate to form the basis for planning decisions in any planning situation. The level of detail and accuracy required for decision-making can be obtained only by the detailed analysis and evaluation of plans through use of the AQUIP System.

In addition, these guidelines, which were derived from regional scale analytical results, are not applicable to the consideration of highly localized (i.e., microscale) effects. For example, CO air quality over short time periods and small distances is more likely to be determined by localized influences, such as peak-hour traffic, buildups of concentrations due to the layout or structure of facilities, or to short-term extremes in meteorological conditions. Thus, even though regional air quality concentrations and impacts may be minor, there may be serious localized pollution problems.

Finally, it must be cautioned that advice concerning the role of air pollution considerations within the land use planning process is not particularly simple to give nor easy to apply: the planner must accommodate many other issues and concerns; he is confronted with numerous constraints ranging from financial resources to social and political attitudes; information upon which to judge the costs, benefits, and other impacts of alternatives is usually inadequate; and the administrative and legal difficulties of implementing proposed plans can be severe. Futhermore, it is not usually the primary concern of land use planning to assume the burden of abatement of existing regional and local air pollution problems; this is more appropriately the function of governmental air pollution control agencies. Rather, the primary objective of considering air pollution in the land use planning process is to augment existing air pollution control measures through appropriate planning measures in order to prevent conditions from occurring in the long-term that would necessitate severe source emission control regulations. The guidelines presented in this document represent considerations concerning air pollution that are appropriate within the planning process to improve region-wide air quality and to reduce the exposure of the general population (as well as high-risk groups within the general population) to high pollutant concentrations.

8. CONCLUSION AND RECOMMENDATIONS

In this Summary Report the basic results of this research effort have been described in brief. Overall the work has focused on developing methodologies for incorporating air pollution into the planning process, applying these methodologies to specific land use plans for the Hackensack Meadowlands, and deriving general planning guidelines from the results. The specific conclusions resulting from each of these efforts have been described in the above sections and are too numerous to summarize conveniently without extensive repetition of text. Rather, this section enumerates the most important end results from this research and development effort, and discusses the general applicability of these methodologies and results to other planning situations. Finally, a number of recommendations are listed which indicate the direction that future research and development efforts should take in order to further promote the development of methodologies and analytical tools for the consideration of air pollution in the planning process.

8.1 Review of Major Accomplishments

As a direct consequence of this study effort, a number of important advances have been made in the consideration of air pollution in the land use and transportation planning process. Among the more significant of these are the following:

1. Analytical tools have been developed that allow the planner to assess air quality associated with land use planning alternatives primarily on the basis of the use of planning input data.

2. Detailed procedures have been developed for the use of such analytical tools for incorporating air pollution considerations directly into the planning process.

3. The use and utility of these procedures and analytical tools have been demonstrated by application to the evaluation of the Hackensack Meadowlands land use plans; the procedures developed are operational tools for application to actual planning situations.

4. The AQUIP System software has been implemented on computer facilities of the New Jersey Department of Environmental Protection, and represents a demonstrated operational working tool for use by planners and air pollution control officials alike.

5. A set of planning guidelines of broad applicability to other similar planning situations has been derived from air quality analysis of the Hackensack Meadowlands land use plans.

Because every attempt has been made to incorporate state-of-the-art technology in the development of these procedures and analytical tools, it is worthwhile to enumerate briefly some of their more significant features.

The AQUIP System is the first tool that permits the use of planning data as a direct input to the assessment of air pollution associated with land use plans. Because the planner must also make use of types of data that he does not normally deal with in the planning process, he may at times not be able to specify all the data required. Through the use of a conversion factors catalogue and sets of default parameters incorporated

into the AQUIP System software, the planner can run the programs despite problems associated with missing or unavailable data. Moreover, the programs are designed to permit easy modification of input data so that as missing data become available (or as better estimates of data, such as emission factors, are made), they can be inserted to update the air pollution analysis. Although the initialization of the data base is a large undertaking, incremental changes to the data base are simple and quick to perform. Consequently, modifications to portions of a plan can be evaluated rapidly and without major revisions to the entire data base.

The AQUIP System represents a land use planning tool that can represent all source geometries in the analysis of air quality. In particular the air quality projection model can treat directly point, line and area sources which can be located at ground level or at any desired elevation. Thus the planner has complete flexibility in the use of the model to represent comprehensive plans including both transportation activities (line sources) and land use activities (point and area sources). The AQUIP System permits the direct input of land use data which can be represented by points, lines or area figures. The lines must be straight-line segments, but can consist of an arbitrary number of links, for example, to represent roadway systems; the area figures must be polygons, that is, the boundaries of areas must be represented by straight-line segments.

The AQUIP System is the first planning tool to have the capability to automatically allocate emissions from these "figure-based" input to "grid-based" data sets. Through this feature of the AQUIP System, emissions can allocated to any arbitrary rectangular grid system specified by the user. Furthermore, any data, e.g., population, specified in terms of the input source geometries can be allocated to the specified grid system.

The ERT/MARTIK air quality projection model incorporates many features that represent improvements over similar gaussian diffusion models such as the AQDM.[5] These features and modifications contribute to improved accuracies in computing concentrations at short distances from sources and to the significant reduction of running times of programs on digital computers. Additionally, the model has been adapted to fit computers with core capacities as small as 55,000 bytes.

This study represents the first effort to apply quantitative multipollutant ranking indices for the evaluation and ranking of land use plans in terms of air quality criteria. It also represents the first effort to develop quantitative multipollutant ranking indices that explicitly take into account the effects of air pollution on specific receptors, including land use categories within the plan.

Finally, the AQUIP System has the feature of providing a computer routine capable of calculating numerous desired air quality impact parameters as specified by the planner. Such computations may involve correlations between land use data and air quality data, or comparisons with specified criteria such as ambient air quality standards.

8.2 General Applicability of the Results

The AQUIP System of procedures and software has been designed to be applied to the analysis of regional scale air quality associated with land use and transportation planning alternatives. Because a major objective of the study was to apply these procedures to the evaluation of ranking of the four Hackensack Meadowlands land use plans, the programmed computation routines and the data sets are in large part based on the characteristics of these plans and the planning assumptions of the Hackensack Meadowlands

Commission. In order to be applied to new planning developments, some new computation routines would have to be written to reflect the appropriate planning assumptions.

In programming the AQUIP System software, however, a deliberate attempt was made to maintain as much generality in the programs as possible. This was done explicitly by structuring the computation routines in a form that makes the main programs completely general, and by utilizing specialized subroutes as necessary to perform calculations that are application specific. Consequently, the overall procedures and computer programs of the AQUIP System are completely general in structure.

The results of the Hackensack Meadowlands air pollution analysis studies were used as a basis for the development of planning guidelines. For the greatest part these guidelines are quite general and can be applied to other regional scale planning situations with two basic provisions. The primary exception is that the explicit quantitative results are less generally applicable. Specifically, these quantitative results may be used for broad planning estimation purposes in other planning situations, but cannot be considered sufficiently accurate to be used as a basis for plan decision-making. The second limitation on the generality of the guidelines is that they represent the characteristic meteorological and topographical conditions associated with the Meadowlands. For example, since the Meadowlands has a relatively flat and homogeneous terrain, the results cannot be applied in planning regions having highly variable or unusual topographical features.

Finally, the AQUIP System can be applied to the analysis of air quality within urban regions for current situations as well as for future time frames. This was demonstrated in the Meadowlands study by constructing the current northern New Jersey emissions inventory for validating and

calibrating the model. Thus the AQUIP System represents a tool that can be used not only by planners during the implementation phases of the planning process to evaluate proposed new developments within the region, but also by air pollution control agencies to address problems such as the evaluation of control strategies necessary to achieve ambient air quality standards involving, for example, changes in traffic levels, transportation systems, land use, fuel use, and emission control regulations.

8.3 Recommendations

The work undertaken and accomplished in this research effort represents an important initial step to quantify the relationships between plan design factors and air pollution. As a consequence of the study there have been a number of questions raised but which remain unanswered due either to constraints resulting from the scope of the research assignment or due to the limitations of time and available resources. Therefore, it is appropriate to review briefly the areas in which it is felt that additional research and development efforts would be highly beneficial to advancing the state-of-the-art in considering air pollution in the planning process.

The recommendations fall into three categories. First are the areas of recommended additional studies using the AQUIP System as already developed. Second, are areas of recommended research efforts and further developments of the AQUIP System for the analysis of regional scale air quality. Third are the areas of recommended research to develop methodologies, analytical tools and planning guidelines: (1) for the consideration of more complex issues in the planning process, such as determining microscale impacts and determining relationships between air pollution and other environmental matters; and (2) for the development of a more generalized analytical framework for plan evaluation, such as cost-benefit studies.

8.3.1 Further Studies Directly Associated with the Planning Process of the Hackensack Meadowlands Development Commission

In conjunction with the planning process of the HMDC, it is recommended that the AQUIP System be used to perform further studies of the existing plans through the analysis of the sensitivity of air quality to variations in plan design factors, especially the mix and relative location of land use categories.

It is further recommended that the AQUIP System, as developed, be applied on a routine basis within the planning process of the HMDC to analyze major modifications to existing plans or to develop entirely new planning concepts as the need arises.

Finally, it is recommended that the AQUIP System, as developed, be used to update and to refine air quality projections as time progresses and as land developments become more explicitly defined. For example, in the future better emissions data will become available to the Meadowlands planners as specific industries are identified. Furthermore, changes in fuel use, control technology, and emission regulations will cause substantial changes in emissions estimates, not only for planned developments, but for existing sources as well.

8.3.2 Further Developments of the AQUIP System for Regional Scale Air Quality Analysis

On the basis of the insight and experience gained as a result of the current study, it is recognized that the AQUIP System can be substantially improved as a planning tool for the analysis of regional scale air quality through additional research efforts. Some of the more significant of these efforts are listed in the following paragraphs:

1. It is recommended that the AQUIP System be adapted to and documented for application to the general planning situation. This would involve an extensive documentation to explain the decision-making processes that go into the development of the explicit computational routines required to automate the planning assumptions and plan characteristics specific to a particular planning situation.

2. It is recommended that further work be done to refine the emissions data, especially in the area of activity indices and projecting indices. It is noted that in general emissions data are available for specific industries, but that the categorization of land use types and activities even in such detail as four or six digit SIC codes is often insufficient to accurately differentiate industries by emissions characteristics.

3. It is recommended that further efforts be devoted to the development of default parameters to better enable the planner to make use of the AQUIP System in situations where he is unable to obtain or specify the required input data.

4. It is recommended that further efforts be devoted to improving methods for projecting background air quality. As demonstrated by the Meadowlands study, background air quality is a particularly important element in the analysis of regional air quality for land use planning and is a particularly large effort in urban regions.

5. It is recommended that further studies be conducted concerning the validation and calibration of the air quality projection

model. In particular there is a specific need to better understand the near field effects of large sources, especially in the vicinity of air quality monitoring sites whose measurements are used to estimate regional air quality levels. There is also a need to have air quality monitoring sites placed in areas representative of regional background levels. Finally, there is a need to measure pollutant concentrations over long base paths in order to provide data for the calibration of models more directly representative of regional average concentrations.

6. It is recommended that further studies be conducted concerning meteorological effects. In particular data and results of research conducted by EPA and other agencies should be incorporated into the model validation. In addition, the validation studies should include an analysis of the systematic correlations that can occur between meteorological conditions and emission sources. For example, nighttime stable conditions should not be applied to emissions which occur predominantly during daytime hours, e.g., pollutants from motor vehicles and industrial processes. Similarly, high correlations between northerly wind directions and large space heating emissions can be expected during the winter months. Such effects are not accounted for in the current techniques for computing annual average concentrations.

7. It is recommended that further studies be conducted to examine the effects of topographical and local meteorological factors on regional air quality. Because of the flat terrain of the Meadowlands, the effects of variations in topographical features could not be investigated. Studies should be conducted to examine local influences such as topography and heat island and sea breeze effects on pollutant concentration patterns, and to coordinate the meteorology associated with urban developments with mesoscale meteorological models.

8. It is recommended that to the greatest extent possible these research studies be carried out using the existing Hackensack Meadowlands data base. In conducting further studies a good data base is essential. Considerable efforts have been devoted to the development of this particular data base, not only to incorporate the most recent and accurage emissions inventory data, but also to code the data in a standardized format for use in the AQUIP System.

8.3.3 Further Developments of the AQUIP System for Other Applications

As discussed above, the AQUIP System represents a tool useful to planners and air pollution control agencies alike for examining air quality impacts resulting from land use developments and state implementation plan control strategies likely to occur in the near future (i.e., from one to five years). In order to facilitate the use of the AQUIP System for such applications:

1. It is recommended that a software interface be developed between the AQUIP System and the computerized data base of an air pollution control agency to permit direct access to current emissions data. This would permit rapid updates of the AQUIP emissions data base and permit rapid recalibration of the models. As a consequence the AQUIP System could be used either by planners or air pollution control agencies to continuously update air quality projections on a regional scale to reflect both actual and potential changes in the emissions of current sources.

2. It is recommended that further efforts be devoted to the refinement of rapid estimation techniques for the evaluation and ranking of land use planes. In particular, it is recommended that studies be conducted to develop sensitivity data relating emissions to land use categories which would be representative of a wide range of planning situations and thus be more generally applicable.

One of the major findings of the ERT survey of land use and transportation planning agencies was that planners need to have information concerning very localized effects of elements of a plan for use during plan design. Because the current AQUIP System methodologies are oriented toward the analysis of regional scale effects, the results of such an analysis cannot be used directly to infer localized or microscale air quality impacts. The AQUIP System, however, can be modified to permit the analysis of such localized effects.

3. Therefore it is recommended that further research efforts be devoted to the development of methodologies for the analysis of land use plans at the microscale level of detail through adaptation of the AQUIP System.

4. It is recommended that detailed sensitivity studies be conducted to develop planning guidelines relating the impact of small-scale elements of the plan on localized air quality levels. These guidelines should include, for example, the effects of open space, cluster developments, and intensity of land use activities on localized air quality, as well as estimates of the near-field region of influence of specific types of land uses. They also should describe relationships between localized air quality and factors such as population density, the location of employment centers, and transportation facilities.

5. It is recommended also that microscale sensitivity studies be conducted to develop planning guidelines relating the impact of the design and arrangement of structures on microscale air quality. Such detailed studies should include the analysis of buildings in terms of characteristics that influence microscale meteorological conditions (such as height, shape, and lot coverage), and in terms of characteristics which influence emissions (such as fuel use, control devices, heating systems and incineration). Likewise, roadway facilities should be examined to assess localized impacts on air quality in terms

of design characteristics such as median width, setback from right of way, and cross-section configuration.

Finally, it is recognized that air pollution is only one of the many considerations of importance to the planner. As a result it is recommended that further research and development efforts be devoted to examining air quality in relation to other environmental and planning issues.

6. It is recommended that research efforts be devoted to the development of techniques for the study of explicit relationships and tradeoffs that may occur between air pollution and other environmental concerns, such as water quality and solid waste management.
7. It is recommended that efforts be devoted to the development of techniques to better assess the impacts of direct concern to planners and citizens alike, such as health effects, damage costs and economic impact.
8. Finally, it is recommended that research efforts be devoted to the development of a more broadly based plan evaluation and ranking methodology. This might include, for example, the consideration not only of direct air pollution impacts, but also indirect impacts resulting from the relationship between air pollution and other environmental concerns or planning issues. In particular the framework for such a plan evaluation scheme might be based on criteria related to the costs and benefits resulting from alternative allocations of regional resources.

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GLOSSARY

Activity, Activity Level - basic land use and transportation planning units of intensity of use - vehicles per day on a highway, acres of residential land use, square feet of industrial plant space.

Activity Index - a numerical conversion factor to transform the level of activity specified for a land use category into demand for fuel for heating purposes.

Air Quality Contour - a contour line in a plane (usually the horizontal or vertical) representing points of equal concentrations for a specified air pollutant.

Air Quality Criteria - factors used in this study that represent a basis for decision-making, for example ambient air quality standards.

Air Quality Prediction - the calculation of current or future air pollutant concentrations at specified receptor points resulting from the action of meteorological conditions on source emissions.

Albedo - the fraction of solar radiation reflected from the ground surface.

Ambient Air - that portion of the atmosphere, external to buildings, to which the general public has access.

Ambient Air Quality - concentration levels in ambient air for a specified pollutant and a specified averaging time period within a given geographic region.

Ambient Air Quality Standard - a level of air quality established by federal or state agencies which is to be achieved and maintained; primary standards are those judged necessary, with an adequate margin of safety, to protect the public health; secondary standards are those judged necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

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AQUIP - an acronym for Air Quality for Urban and Industrial Planning, a computer-based tool for incorporating air pollution considerations into the land use and transportation planning process.

Atmospheric Boundary Layer - the lower region of the atmosphere (to altitudes of 1 to 2 km) where meteorological conditions are strongly influenced by the ground surface features.

Atmospheric Dispersion Model - a mathematical procedure for calculating air pollution concentrations that result from a specified array of emission sources and a specified set of meteorological conditions.

Average Receptor Exposure - a measure of the average impact of air quality levels on specific receptors; the measure is based on the integrated receptor exposure divided by the total number of receptors in the study region.

Background Air Quality - levels of pollutant concentrations within a study region which are the result of emissions from all other sources not incorporated in the model for the study region.

Background Emissions - the emissions inventory applicable to the background region; that is, all emission sources not explicitly included in the inventory for the study region.

Climatology - the study of long term weather as represented by statistical records of parameters such as winds, temperature, cloud cover, rainfall, and humidity which determine the characteristic climate of a region; climatology is distinguished from meteorology in that it is primarily concerned with average, not actual, weather conditions.

Concentrations - a measure of the average density of pollutants usually specified in terms of pollutant weight per unit (typically in units of micrograms per cubic meter), or in terms of relative volume of pollutant per unit volume of air (typically in units of parts per million).

Default Parameters - values associated with a parameter for a category of activities (such as heavy manufacturing) assigned to the activity parameter for a subcategory of activities (such as electrical machinery production) when the actual value for the subcategory is not known.

Degree Days - the number of degrees the average temperature is below 65° each day; used to determine demand for fuel for heating purposes.

Effective Stack Height - the height of the plume center-line when it becomes horizontal.

Emission Factor - a numerical conversion factor applied to fuel use and process rates to determine emissions and emission rates.

Emissions - effluents into the atmosphere, usually specified in terms of weight per unit time for a given pollutant from a given source.

Emissions Inventory - a data set describing the location and source strength of air pollution emissions within a geographical region.

Emissions Projection - the quantitative estimate of emissions for a specified source and a specified future time.

Equivalent Ambient Air Quality Standards - air quality levels adopted in this study to permit analysis of all air pollutants in terms of annual averages; in cases where state and federal annual standards do not exist, the adopted levels are based on the extrapolation of short period standards.

Fuel Related Sources, Fuel Emissions - fuel related sources use fuel to heat area, or to raise a product to a certain temperature during an industrial process, or for cooking in the house; they produce fuel emissions. (See also Non-Fuel Related Sources.)

Fuel Use Propensity, Fuel Demand - the total heat requirement (space heating plus process heating) determines the fuel demand; the propensity to use a particular fuel or fuels determines the actual amounts of various fuels used to satisfy the heat requirement.

Heating Requirements - the demand for fuel is specified in terms of the heating requirements:

space heating - the fuel used to heat area, such as the floor space of a school in the winter, is that required for space heating; the heat content or value of that fuel defines the space heating requirement (BTUs, British Thermal Units of heating content).

non-space heating, process heating - the fuel used to raise a product to a certain temperature during an industrial process or for cooking (with gas) in the home is that required for process heating or non-space heating. It is generally not related to outside temperature whereas space heating requirements are.

percent space heating, percent process heating - the relative proportion of a fuel or its heat content that is used for space heating or process heating defines,respectively, the percent space heating or percent process heating.

Impact Measure (or Parameter) - a quantitative representation of the degree of impact on air quality or specific receptors resulting from concentrations of specified pollutants.

Influence Region - the influence region for a study area is the geographical region containing the emission sources responsible for at least 90% of the ground level concentrations (averaged throughout the study area) of all pollutants considered.

Integrated Receptor Exposure - a measure of the total impact of air quality levels on specific receptors; the measure is based on the summation within the study region of the number of receptors times the concentration levels to which they are exposed.

Inventories - the aggregation of all fuel and process emissions sources is called the emissions inventory; the components for use with the model:

current inventory - all sources for 1969

background inventory - all sources for 1990 not directly related to the meadowlands plans.

plan inventories - all sources for 1990 related to the Meadowlands plans; this excludes any source outside the Meadowlands boundary and also excludes existing major single sources and the highway network.

Isopleth - the locus of points of equal value in a multidimensional space.

Land Use Intensity - the level of activity associated with a given land use category, for example the population density of residential areas.

Land Use Mix - the percent of total study region area allocated to specific land use categories.

Meteorology - the study of atmospheric motions and phenomena.

Microscale Air Quality - the representation of air quality in a geographical scale characterized by distances between source and receptor ranging from a few meters to a few tens of meters.

Mixing Depth - the vertical distance from the ground to the base of a stable atmospheric layer (also called inversion height).

Model Calibration - the process of correlating model projections with observed (measurements) data, usually to determine calibration factors relating predicted to observed values for each pollutant.

Model Validation - the detailed investigation of model results by comparison with measured values to identify systematic discrepencies that may be conected by alterations of model parameters or model mechanics.

Non-Fuel Related Sources, Process Emissions, Separate Process Emissions - non-fuel related sources do not burn fuel primarily for heating purposes or do not burn fuel at all; these include transportation sources, incineration, and certain industrial processes; they produce process or separate process emissions. (See also Fuel Related Sources.)

Ranking Index - a quantitative representation of the net impact on air quality or specific receptors resulting from all pollutants being considered.

Receptor - a physical object which is exposed to air pollution concentrations; objects may be animate or inanimate, and may be arbitrarily defined in terms of size, numbers, and degree of specificity of the object.

Receptor Point - a geographical point at which air pollution concentrations are measured or predicted.

Regional Air Quality - the representation of air quality in a geographical scale characterized by large areas, for example, on the order of 50 square kilometers or greater.

Schedule - number of hours per year a fuel burning activity will consume fuel; used to determine heating requirements.

Source - any stationary or mobile activity which produces air pollutant emissions.

Source Geometry - all sources for modeling purposes are considered to exist as a point, line, or area, defined as follows:

point source - a single major emitter located at a point.

line source - a major highway link, denoted by its end points.

area source - a rectangular area referenced to a grid system; includes not only area-wide sources, such as residential emitters, but single emitters and highway links deemed too small to be considered individual point or line sources by the model.

Stability Category - a classification of atmospheric stability conditions based on surface wind speed, cloud cover and ceiling, supplemented by solar elevation data (latitude, time of day, and time of year).

Stability Wind Rose - a tabulation of the joint frequency of occurrences of wind speed and wind direction by atmospheric stability class at a specific location.

Total Air Quality - the air quality at a receptor point resulting from background emission sources and from emission sources specifically within the study region.

Trapping Distance - the distance downwind of a source at which vertical mixing of a plume begins to be significantly inhibited by the base of the stability layer, and gaussian vertical distribution can no longer be assumed.

Wind Sector - a 22-1/2 degree wind direction range whose center-line is one of the sixteen points of the compass.

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